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HANDBOOKS

COTTON
SPINNING

R. MARSDEN

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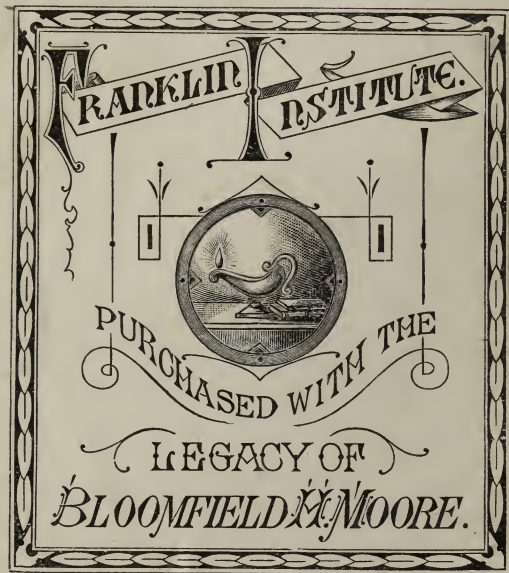
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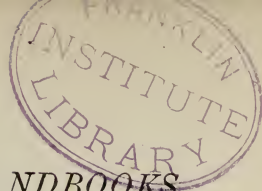


TECHNOLOGICAL HANDBOOKS.

EDITED BY H. TRUEMAN WOOD,

Secretary of the Society of Arts.

COTTON SPINNING.



TECHNOLOGICAL HANDBOOKS.

COTTON SPINNING:
ITS DEVELOPMENT, PRINCIPLES,
AND PRACTICE.

BY
RICHARD MARSDEN, MEMB. SOC. ARTS.
EDITOR OF "THE TEXTILE MANUFACTURER."

WITH AN
APPENDIX ON STEAM ENGINES AND BOILERS.

R LONDON: GEORGE BELL AND SONS,
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PREFACE.

THE impetus recently given to technical education in this country, whilst it has induced a great demand for books suitable for the use of students in our various industries, has revealed in our literature a remarkable deficiency of this class of works. A want of this kind, however, cannot long exist without a supply being forthcoming, and already there are prospects of its early gratification.

The following little treatise has been written with the view of providing, partially at least, for the needs of students of the cotton trade. Until within the past few years this trade has, with rare exceptions, been so profitable, that persons having little or no knowledge of it, who invested capital therein, hardly ever failed to secure a good return. But this is the case no longer : the growth of competition, both domestic and foreign, has reduced profits to such a low point, that to conduct a cotton-spinning business successfully to-day requires that those having charge of it should be either themselves, or in the persons of their trusted servants, thoroughly conversant with both the principles and details of every process through which the material must pass to reach the mercantile form. A correspondingly perfect acquaintance with the market is also required in order to conduct the commercial section of the business safely and profitably. The former is necessary in order to enable those in charge to exercise strict supervision over every *employé*, to enforce care and

economy in the use of the materials, and to detect and rectify any fault that may occur, as only by these qualifications and this procedure can the best results, from a productive point of view, be finally assured. It should be the aim of all practical men having charge of mills to do this, and their pride to accomplish it. A good article in yarns can always be sold ; indeed, it has almost become a proverb that it "will sell itself, and at a profit." The more thoroughly this practical knowledge is also possessed by managers, foremen, and operatives, and is carefully and conscientiously applied by each in the performance of their duties for the benefit of the establishment, the greater will be the certainty of success. The recognition of these truths in connection with cotton spinning, and of corresponding truths in other industries, lies at the basis of the public anxiety for the inauguration of a general and sound system of technical instruction, and the favour with which all efforts to provide one have been regarded.

In undertaking the task of preparing the following essay, it became necessary to recognize the fact that it might be called into requisition by various classes of students and readers, and that as its prescribed limits would prevent an exhaustive treatment of each portion of the subject, the best plan to pursue would be that of dealing most fully with the phases of the question that had been least touched upon by previous writers, or those on which former notices had become obsolete. Dr. Ure's well-known work on the cotton trade is by far the most detailed exposition of the industry that has been published in this country ; the author, however, was not practically acquainted with his subject, and evidences of this frequently present themselves to the technical reader. At the time it was published, however, it was a remarkably valuable exposition of the rising industry, and may be studied with advantage even now. It will be obvious, however, that for most practical purposes the progress of mechanical invention, and improvement in processes, have long ago

rendered it quite obsolete. The same remarks will apply to the treatise of Mr. James Montgomery, only in a less degree, as his intimate practical acquaintance with the cotton trade as then conducted, has rendered his observations permanently valuable, and the student may read his book with benefit to-day. Since his work appeared, many others have been published by various writers, but nearly all have been bald compilations of rules and examples of calculations generally employed in making changes in the various processes. As these are easily accessible to every one, it has not been thought necessary thus to occupy space in the following pages that might be usefully devoted to the more neglected aspects of the industry. In mentioning the above works, it would be invidious not to refer to the more recent and valuable treatise of the late Mr. Evan Leigh, in which much useful information of a practical character is embodied. Its high price, however, places it quite beyond the reach of many of those to whom it might prove useful.

In the following pages the writer has endeavoured to give the reader a concise view of the origin and present extent of this great trade; the material it deals with; the general principles that contribute to its successful conduct; the proper location and construction of a mill, and arrangement of the machinery; and the various processes of mixing, opening, carding, combing, drawing, roving, spinning, and, finally, doubling. In connection with these it has been attempted to trace the development, describe the function of the leading parts, and show the working of the various machines employed in the trade. The least consideration will show that some such course as this was absolutely necessary, as the machines are so numerous and so exceedingly complex in their structure, that to begin their study without a clear and well-defined plan would be to involve the pupil in a state of confusion from which self-extrication would be almost impossible. It is hoped that the course adopted possesses these merits, and that the

reader, after perusal of the subsequent pages, will have obtained an approximately exact and succinct view of the development, leading principles, and present state of England's greatest mechanical industry.

R. M.

MANCHESTER, February, 1884.

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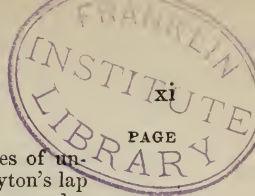
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COTTON SPINNING.

CHAPTER I.

INTRODUCTORY.

Importance of the English or modern system of cotton spinning.—Cotton; origin of its manufacture; the distaff; the spinning wheel; imperfect development of the Hindoo faculty of inventiveness.—Confinement of the ancient system to India; the domestic wheel; the flax wheel.—Kay's inventions; Hargreaves'; Arkwright's; influence of these upon other textile industries.—Development of the new system.—Its extension to the United States; the Continent of Europe; Asia; other parts of the world.—Its present magnitude.—Abundance and cheapness of its products.—Its early influence upon Lancashire; rapid growth; decline of the value of its products.—Present condition; official returns, 1880; inadequacy of these to express its importance.—Location and future prospects of the trade.—Magnitude as compared with other leading industries.

OF the many industrial arts whose products minister to the welfare and happiness of mankind, few have acquired a more important position than the English, or modern, system of cotton manufacturing, or have had a greater influence upon the progress of civilization. The inventions which inaugurated the present epoch of mechanical discovery, occurred in connection with it; and this example in succession spreading to all the other great industries, has, during the past century and a half, revolutionized the condition of civilized society, and made its influence felt throughout the world.

Cotton, the raw material with which the manufacture deals, is the fibrous covering of the seed of the *Gossypium*

herbaceum and kindred plants, which flourish in a state of nature over the tropical and temperate zones of the earth's surface. In India and China the plant has been cultivated for ages, and its fibre utilized in the manufacture of clothing, and also in several other eastern countries. More recently it has attracted attention for the same purpose in the West Indies, the Southern States of the American Union, Brazil, Egypt, and other lands deemed suitable for its cultivation. To many of these it has proved a source of great wealth, and its growth is daily extending, especially in the United States.

The best evidence yet obtained points to India as the birth-place of the manufacture. In that country mechanical appliances appear to have been first invented in order to aid in the manufacture of the fibre. At a very early period the art became a prevalent domestic industry, and extended over almost the entire peninsula; at one time being so general as to employ, more or less entirely, almost half the population. Cotton was grown in the precincts of every village; cleaned, spun, and woven on the spot; each little community producing enough for its own consumption. A rudely-constructed roller gin separated the seed from the fibre, and the latter was cleansed from leaf, sand, dirt, and knots by the bow. The cotton as left by this instrument in a light fleecy mass, was then taken, with little further preparation, and spun by women. The coarsest yarns were made upon a heavy, clumsily-constructed, one-thread wheel, evidently the progenitor of the domestic wheel long in use in this country, and the Saxony wheel of a later date. This was unsuited, however, for the production of the fine yarns used in the manufacture of the exquisitely beautiful muslins of the country, which were therefore spun by means of the spindle that had been in use from time immemorial. A distaff was sometimes employed, though quite as often the process was conducted without. This spindle in the earliest times was composed of a straight piece of wood, weighted at one end with a

bit of clay. Subsequently an iron spindle was substituted, though at what date we are without information. It is also equally impossible now to discover at what period the crude wheel just mentioned was invented, though doubtless it was subsequent to the invention of the spindle. It is strange that the inventive skill of the Hindoo races never produced anything beyond these rude appliances, whilst they attained such a high degree of technical skill in their use. But such is undeniably the fact, for from the day when these simple devices left the inventor's hands, they scarcely appear to have been touched, though ages have passed away since that time, during which they have been in constant use in the hands of millions of workers. The same sterility characterized their efforts in dealing with the machinery they invented for weaving: nothing mechanical of theirs ever grew by a succession of improvements to a condition approximately perfect, as in this country has been the case in almost every instance. It would appear that the epoch of mechanical invention was not destined to be inaugurated by or amongst these peoples.

Cotton manufacturing does not seem to have spread far from the place of its origin, or to have risen to any degree of excellence anywhere out of India until quite recent times. The distaff and spindle, and the rude wheel before referred to, continued the only instruments by which yarn was produced. About the year 1530 the domestic hand spinning-wheel appears to have been invented, and for a long time was the only improvement made. This was succeeded towards the close of the century by the Saxony wheel, which, though a great advance upon the preceding, was a long time in displacing it. This wheel was supplied with a "flyer," by means of which the twist was put into the yarn, and the latter wound upon a bobbin. A traverse movement was afterwards added, enabling the yarn to be run upon the barrel in even layers. A second spindle was subsequently adapted to this wheel, which ob-

tained for it the denomination of the "two-handed wheel," an expert spinner being thus enabled to spin two threads at a time. This constituted the climax of hand spinning.

In the fourth decade of the eighteenth century the elder Kay, of Bury, in Lancashire, invented the picking-stick for the hand loom, added boxes to its sley, and improved the shuttle, enabling one weaver to operate a loom where two were formerly required, the single operative also doubling the production of cloth as compared with the amount obtained before. This was the beginning of the modern epoch of invention, and its first practical result. The demand for yarn, which was a consequence of the general adoption of Kay's improvement, greatly stimulated invention, but a considerable time elapsed before any further real progress was made. Hargreaves, the Blackburn weaver, was the first to succeed with his spinning-jenny in 1767, Arkwright following closely after with his water-frame. On these well-known inventions it is not necessary to dilate here, as the principles embodied in them will come under review subsequently. It must suffice to remark that they form the base of the modern system of cotton manufacturing, and the important results that have sprung therefrom. The influence exerted upon all the textile industries by the successful application of machinery to the performance of the delicate processes of the manufacture of cotton, and the adaptation of cotton machinery to the manufacture of wool, silk, and flax, is a tale which must be relegated to the historian for narration, as also must be the story of the far-reaching influence of these examples upon other industries. Industry has put on a new face, and social conditions have been revolutionized. With philosophers and statesmen, however, may be left the solution of the great politico-economical and social problems that have arisen from the stimulus given to invention by these successes, and the consequent universal application of machinery to industrial purposes, resulting, as it has largely

done already, and will to a greater extent in the future, in the supersession of manual labour. On the correct solution of these problems will depend, to a great extent at least in the early future, the welfare and happiness of vast masses of the human race.

As might naturally be expected, cotton manufacturing has continued to engross a large share of the attention of inventors, and their utmost efforts have been expended in developing and perfecting its appliances. This devotion has been fully rewarded, as the result of their labours has proved of inestimable value. The machinery employed in cotton manufacturing is the result of more mental labour, and the subject of more improvements and patents than any other that can be named. Most of these have sprung from the English manufacturing districts, as was to be expected from the great concentration of the industry in those localities, and the knowledge consequently gained of its further requirements, and experience of the means by which defects could be overcome.

Next in the importance of their inventions and improvements to the English districts must be ranked those which have been brought out in the United States by the emigrants from England and their descendants, who carried the new industry across the Atlantic, and have since kept it nearly abreast in its developments with that of the home country. This has been accomplished, firstly, by the continued importation of skilled workpeople and improved machinery, and, secondly, by original invention. The new conditions by which the transplanted industry was surrounded have led to improvements of a special and important character, and which of late years have obtained, as they have deserved to do, the careful consideration of English machinists and spinners.

The attention of the continental nations of Europe was drawn to the new industry with which England had endowed the world at a very early date; but owing to obstacles for a time naturally placed in the way to prevent

them, these communities did not acquire a knowledge of its appliances quite so soon as did the United States: One reason for this was, that in the States there was no lingual difficulty to encounter. All obstacles were, however, eventually overcome, and the industry has since been planted in nearly every country of the Continent. It is, however, only from France, Switzerland, and Germany that any contributions in the shape of improvements towards perfecting or developing its machinery have been received. Whether this is owing to a deficiency of the inventive faculty or not amongst the people of these countries, we need not try to decide; but it is a standing ground of complaint amongst English machinists that their continental competitors confine their efforts mainly to imitating the devices and inventions first brought out in this country, instead of devoting their energies to the origination of something new. Whether this complaint is just or not, there is certainly not much original matter relating to improvements in cotton machinery that will reward the labour of the inquirer into the records of continental invention; and the little that may be discovered cannot be regarded as particularly important.

In the countries of Asia the new system of cotton manufacturing has yet obtained no hold, if we except India, into which it was introduced by English enterprise about thirty years ago, and where it has continued to make steady progress, favoured by certain local conditions and the fiscal policy of the Government. Whether its development will continue at the same rate now that several of these circumstances have been modified, is a question that only the future can solve. China and Japan have recently made tentative efforts in the direction of introducing this industry amongst their peoples, but as yet not much success has attended these efforts. It will not be a matter of surprise should the latter country, however, achieve a considerable degree of success, and that at no distant date. The strenuous efforts its government has put forth during

the last ten or twelve years to make its people familiar with the manufacturing arts of the West, is a phenomenon of which the latter should not fail to take note, as it may lead to important consequences which will seriously affect the hold that Western nations now have upon Asiatic markets.

In other parts of the world, such as the western side of the North American continent, the central portions, and the southern half of the same continent, the amount of cotton manufacturing is practically nothing, the wants of the people in this respect being supplied from other centres of production. Australia and New Zealand come in the same category. In the vast continent of Africa the modern industry is unknown; the little that is manufactured from the indigenous cotton plant which grows wild in the interior being wrought up by the most primitive of appliances that have ever been used.

The present magnitude of the industry will be adequately represented by the following figures, which form an estimate based upon the most recent information as to the number of spindles, excluding doubling spindles, in Europe, the United States, and India, at the present time:—

	1883.
Great Britain	42,000,000
Continent	22,000,000
United States	12,750,000
India	1,750,000
Other countries	1,500,000
Total	<hr/> 80,000,000

If, therefore, we take the spindles of the world to amount in round numbers to 80,000,000, it will not be far from accuracy. The spinning capacity of these spindles is almost inconceivable. Let us assume that they are constantly working, say, for fifty hours per week, spinning yarn of an average of thirty hanks of 840 yards each to 1 lb. The

speeds at which the machinery in the great spinning centres of England are now working is such as to give a production of 7 yards of yarn to each spindle per minute, but this will doubtless be considerably in excess of that in other localities. It will, therefore, be safer to take 6 yards as the average production per minute per spindle, or a total of 18,000 yards of yarn each per week. Those who are curious in figures may pursue this thought at greater length and in many directions, in all of which the most interesting results may be attained. Thus much, however, will suffice to show to what an important extent mechanical automatic labour has displaced manual industry, and to what an amount the inventions of Hargreaves, Arkwright, and Crompton have alleviated in this one sphere alone the burden of human labour, or in other words have extended the blessings implied by the abundance and cheapness of the products of the cotton trade.

The abundance and cheapness of the products of the cotton manufacture will best be illustrated by a few figures. According to the estimate of Messrs. Ellison and Co., the eminent Liverpool cotton brokers, the 42,000,000 spindles of this country consume 71,000 bales of cotton per week of an average weight of 400 lbs. per bale. This is equal to 1,420,000,000 lbs. per year of fifty weeks, two weeks being allowed for holidays and stoppages. The actual weight given by the same firm for the season 1881-2 rather exceeds this total, being 1,478,997,000 lbs. This vast weight of raw material was worked up into yarn and cloth, and after supplying our domestic requirements, we exported to foreign countries, including our colonies and dependencies, in the same season, 244,300,000 lbs. of yarn, and 4,456,000,000 yards of cotton goods, totals in both heads rather less than those of the previous year. The spindles of the Continent spin on an average lower numbers of yarn, and therefore require a correspondingly larger supply of the raw material. The consumption of the Continent for the same season was 1,207,650,000 lbs. The

total consumption of the American continent may be set down at 2,000,000 bales per annum, or 960,000,000 lbs., which amount is annually increasing. To these vast quantities there is yet to add the amount required by the Indian spindles, which will be about 140,000,000 lbs. Taking the consumption of the American continent at 1,000,000,000 lbs., the total of these vast figures amounts to 3,767,650,000 lbs., or 9,419,125 bales of 400 lbs. each. This material, estimated on an average at 5*d.* per lb., will nearly equal a sum of £78,500,000. In the processes of manufacture this enormous sum is probably quadrupled by the addition of the skill, labour, and interest of the capital necessary for the conversion of this amount of cotton into its various commercial products.

Not less important has been the influence of the rise of this industry upon the districts in which it is chiefly carried on. In 1750 the population of Lancashire was only 297,400, and the manufacture then existing was purely of a domestic character. Ten years later, the number of people engaged in the English cotton manufacture was estimated to be only about 43,000 persons, the product of whose labour would not equal that of 1,000 persons to-day. In 1770 the populations of Bolton and Blackburn were respectively about 5,000; at present, both of these towns exceed 100,000; and owe their growth to the development of this industry. At the same period, the population of Manchester was 40,000. The aggregate population of the group of towns now included under the same designation is probably fifteen times this number, thus showing a growth nearly proportionate to that of the smaller towns just mentioned. The influence of Hargreaves' and Arkwright's inventions were just then beginning to be felt in the great stimulus given to invention and industrial enterprise. In 1775 the number of operatives employed in the trade had increased to 80,000, whilst the amount of cotton imported had grown to 18,500,000 lbs. The factory system may be said at this date to have just taken root.

Twelve years later, or in 1787, the number of factories had increased to 143, containing 550 mules on Crompton's principle, and 20,700 jennies on the plan of Hargreaves, which by this time had received some important improvements. The number of water frames on Arkwright's principle cannot be ascertained; but the total number of spindles at work on the three systems in this year is estimated at 1,951,000, the cost of which, and of the auxiliary machinery, together with the buildings in which they were contained, reached in the aggregate £1,000,000. The number of operatives directly employed in the industry was supposed to be 26,000 men, 31,000 women, and 53,000 children, or 110,000 in all. In the subsequent stages of manufacture the number of persons employed was similarly estimated to be 133,000 men, 59,000 women, and 48,000 children. These constituted a grand total of 350,000 persons. In the same year, the raw material consumed slightly exceeded 22,000,000 lbs. The estimated annual value of the cotton manufacture at this time was £3,304,370, against £600,000 in 1767.

In 1785 Cartwright first invented the power loom, and in the year under notice, 1787, took out his second patent for the same machine, which he had greatly improved. In this year cotton machinery was first introduced into France, and the first cotton mill was built in the United States. The systematic cultivation of cotton in Georgia and Carolina was commenced as a commercial speculation in 1788. In the year following the first steam engine used for cotton spinning was erected in the mill of Mr. Drinkwater, Manchester, by Messrs. Boulton and Watt. The parish of Oldham, now the greatest spinning centre in the world, at this time had only a population of 13,916. Progress after this date was rapid, and need not be traced in any further detail. A host of inventors were engaged upon improving the existing, and devising new machinery. Their efforts in various degrees were successful. Samuel Slater, an apprentice of Arkwright's, had gone to America,

and was employed in imitating the machinery amongst which he had been trained. The improved machinery of Lancashire was smuggled out of the country to the Continent, in spite of stringent laws to prevent its exportation.

The rapid increase in the productive power of the new machinery frequently led it to overrun the distributive agencies then at work, and gluts succeeded one another rather frequently. The decline of values consequent on these conditions stimulated demand, which absorbed supplies, and quickly led to further extensions of machinery. Repetitions of these occurrences have constituted a great portion of the history of the trade, from the beginning of the current century to the present time. The most notable crisis in its history was the occurrence of the cotton famine in Lancashire, which arose from the war of Secession in the United States. This sprang from a movement having in view the preservation of the institution of negro slavery in the Southern, or cotton growing, States, which had grown to enormous proportions with the rise of the cotton trade. As every one knows, this cherished institution perished in the war; and its downfall is now generally regarded, even in the cotton States themselves, as a satisfactory result. Since that time there has been little to chequer or retard the progress of the trade beyond the recurrence of times of prosperity and depression.

The official returns of 1880 show that in England and Wales there were at that date 2,579 cotton factories, 2,482 of which were situated in what is known as the manufacturing districts of Lancashire, Yorkshire, Cheshire, and Derbyshire, the remaining ninety-seven being scattered over other parts of the country. Scotland, at the same time, had eighty-nine mills, and Ireland six, also devoted to the manufacture of cotton, thus giving a total of 2,674 for the United Kingdom. At that time these mills contained 39,527,920 spinning spindles, 4,678,770 doubling spindles, and 514,911 power looms. The staff of work-

people was composed of 185,472 males, and 297,431 females. These numbers included 61,923 children under thirteen years of age, who were "half-timers." The total number of people thus directly employed in the cotton trade of this country alone was thus 482,903, which has probably increased since the date of these returns to 500,000.

The above figures, however, very inadequately express the magnitude and importance of this gigantic industry, for they embrace none of the subordinate and dependent branches. These include that portion of the iron trade engaged in the production of cotton machinery; the coal trade employed in providing fuel to supply its motive power; the furnishing trades which provide its numerous accessories; the bleaching, finishing, printing, and dyeing trades, that take its productions as they leave the mill; the carrying trades, which transfer its raw materials and products from one part to another, and finally distribute them to all parts of the world; and, lastly, those who take charge of its merchandise, no insignificant number in themselves. These vastly increase the aggregate of persons employed, and enlarge the general importance of the trade.

From this brief description it will be seen that the growth of this industry is one of the marvels of modern times. Whether the same rate of progress can be maintained or not in the future, as has been shown in the past, is a question that excites in thoughtful minds a great amount of interest, but the answer to which must be left for time to reveal. It may be safely said, however, that the present centres of the trade are not likely to be easily deposed from the position of eminence which they have acquired. Geographical location, climatic influences, and geological developments are amongst the chief conditions that control its successful conduct; and the character, training, and acquired skill of the people who are engaged in it, are elements that cannot be disregarded. There are

comparatively few spots on the earth in which the necessary conditions and advantages exist, combined in the same degree as they are found in the manufacturing districts of England; hence those interested may look forward with confidence to its maintaining its supremacy. Buttressed by protective tariffs, manufacturing may be carried on successfully in other countries not so suitably adapted to the purpose by natural conditions; but with the progress of education which is taking place in all communities, the impolicy of allowing one section of a community to grow rich at the expense of the rest, will become so strongly obvious that the economic fallacy of protection will perish for want of support.

This short review will show that whether judged by the amount of capital invested, the number of people employed, or the area over which it is spread, the cotton trade must be admitted to have but few rivals, and hardly any equal in importance, after precedence is given to the great pastoral and agricultural industries whose object is to provide the food supplies of mankind. To those persons, therefore, whose capital, skill, and life's labour is invested in it, scarcely a more important inquiry can be presented than one having for its object an elucidation of the means by which the most satisfactory results may be attained, and each individual be enabled to direct his efforts to their accomplishment. To answer such an inquiry is the object of the following little treatise; and if the writer's effort be only approximately successful, the end in view will be attained.

CHAPTER II.

COTTON.

Cotton : its order, genus, species, and characteristics.—Possible cotton lands ; countries in which it is cultivated.—Geographical names.—Suitable soils for growth ; preparation and sowing ; picking season ; picking ; mechanical picking not successful.—American crop ; area ; cost of production ; variations in quality and their causes ; adulteration.—West Indies.—Central and South America ; indigenous variety.—Egypt ; extent of crop ; indigenous and exotic varieties ; characteristics.—India ; extension of cultivation.—Other Asiatic countries : China ; Japan and Java ; Bokhara and Turkestan ; Asiatic Turkey ; Syria and Persia ; Cyprus.—European countries : Turkey, Greece, Italy, and Spain.—Differences of quality.—Geographical names the best.—Tabular statement of leading varieties : countries of production ; names ; districts where grown ; length of staple and diameter of fibre ; descriptions ; capabilities and uses.—Principle of classification ; classification of leading varieties.—Standard qualities and variation of these.—Careful selection required.—Mechanical structure of the cotton fibre : the cotton pod ; stages of growth ; the seed ; the fibre ; growth of the latter ; causes of its twisted or convolute form ; immature and undeveloped fibres.—Its mechanical structure, the basis of its usefulness.—Recent curious discovery by the microscope.—Cotton fibres compared with the other textile fibres.—Important general principles in spinning and manufacturing deduced from experience.

NO plant, considering its importance to mankind, has received less attention from scientific men than the cotton plant. This is probably owing to its habitat being outside the countries where science has been most highly cultivated. The consequence is that amongst botanists there prevails considerable differences of opinion concerning the number of species and varieties that exist. The plant is classed in the order *Malvaceæ*, under the name of *Gossypium*. Linnæus divides the genus into five species ; De Candolle reckons thirteen ; and other botanists have enlarged this number. But Dr. Royle, a most careful investigator, re-

duces the number to eight, and believes that these can be brought down to four primary ones, namely, *Gossypium herbaceum*, *arboreum*, *hirsutum*, and *Barbadense*.

The first-mentioned of these species, the *Gossypium her-*



Fig. 1. *G. herbaceum*.

baceum, grows from four to six feet high, bearing a yellow flower. The seeds are covered with a short grey down, whilst the fibre it bears is classed short. It is found native or exotic in Egypt, Asia Minor, Arabia, India, and

China. The short stapled variety of Egyptian cotton is of this species. Fig. 1 is a representation of this plant. The Indian cottons are the product of a variety named by Lamarck the *G. Indicum*. This grows from eight to ten feet high, and, like the allied species generally, bears a yellow flower, the seeds being downy, and the fibre short-stapled and very white. Figs. 2 and 3 show the fibres of these two plants enlarged under the microscope, the first being Surat and the second Smyrna cotton, shown upon micrometer lines on glass $\frac{1}{1000}$ of an inch apart.

The *Gossypium arboreum*, when full grown, attains a height of from fifteen to twenty feet, from which fact it derives its name. The flowers are red, the seeds covered with a greenish-coloured fur, and enveloped in a fine silky wool, yellowish-white in colour. It is found in Egypt, Arabia, India, and China.

The *G. hirsutum* is a shrubby plant, its maximum height being about six feet. The young pods are hairy, the seeds numerous, free, and covered with firmly-adhering green down, under the long white wool. It is probable that this is the original of the green-seeded cotton, now cultivated so extensively in the Southern States of the American Union, and which forms the bulk of the supply from that source.

The *G. Barbadense* (Fig. 4) grows to the height of from six to fifteen feet. Its flowers are yellow, and its seeds black and smooth, being quite destitute of the hair that distinguishes several members of the species. As implied by its name, it is a native of Barbadoes, or has been cultivated there for a long time. The cottons most highly esteemed in commerce belong to this species, having probably undergone only slight modification as the result of climatic influences and variations in the method of cultivation. The Sea Island and Bourbon cottons, from which the fine yarns used in the manufacture of lace are made, the long-stapled Egyptian, and several other good varieties, are said by some writers probably to be from this

Fig. 2. Surat.

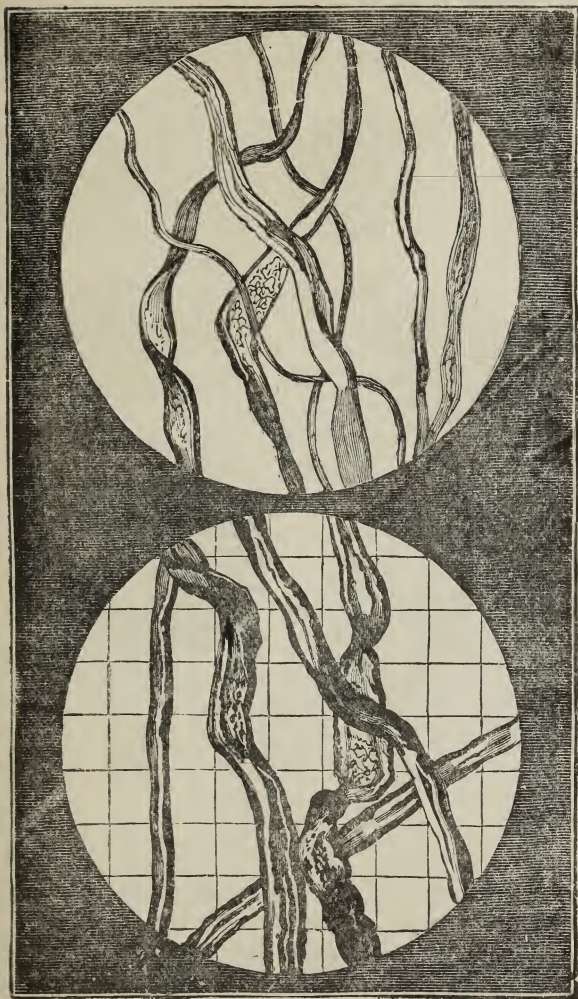


Fig. 3. Smyrna.

stock, as they possess many points of identity or resemblance. If this is so, it has, however, undergone considerable alteration by its transfer to new localities, and changes in the method of cultivation, as may be seen from the



Fig. 4. *Gossypium Barbadense*.

annexed drawing, Fig. 5. Fig. 6 shows the fibres of the Sea Island variety as enlarged under the microscope.

A remarkable species or variety, the *Gossypium religiosum*, exists in India. It has for ages been devoted to the manufacture of clothing for the Brahmins, the religious caste of Hindoo society ; it is arborescent, and carries a

purple bloom. The seed is stated to be small, nearly globular, covered with a greyish-white down and some hairs, of which those round the point are much longer



Fig. 5. Sea Island plant of Georgia.

than the seed, though few in number. Two varieties are known—those of Wanquebar and Cambaye. The yield is very small from both of them, and the filaments being condensed closely round the seed, renders it unfitted for

ginning. It is therefore hand-picked, and takes a woman from twenty-six to thirty hours to pick one pound of lint. Formerly it was picked by nuns, whence one of its names, "nuns' cotton." Fig. 7 shows the fibre enlarged under the microscope.

It will probably be best to let this general description of the most strongly-marked species suffice, because botanists have never yet agreed about the characteristics upon which subdivision into varieties should take place, all the points hitherto selected for this purpose having proved unsatisfactory.

Whether the cotton plant is a native of India, and from that country has spread over the localities in which it is now found, or whether it is indigenous to several of them, is a moot point amongst authorities, and one which there need be no attempt made to decide here, as either natural agency or human instrumentality may be regarded as sufficiently powerful to have accomplished the result. Those parts of the world in which cotton is or can be grown constitute a broad zone extending 45° north to 35° south of the equator. Reference to a map will show that it includes a space extending from the European shores of the Mediterranean to the Cape of Good Hope, from Japan to Melbourne in Australia, and from Washington in the United States to Buenos Ayres in South America, with all the lands intermediate between these several points. These include the Southern States of the American Union, from Washington to the Gulf of Mexico, and three-fourths of South America, the whole of the African continent, and Southern Asia from the Bosphorus to Pekin in China. The vast area of Australia is also within the cotton zone, and the islands lying between that country and Asia. It will thus be seen that however large the ultimate demand may become, the supply will not fail for want of land in suitable climates on which to produce it.

At present, however, cotton is cultivated over only a limited area. In many countries it is grown to a small extent,

Fig. 6. Sea Island cotton.

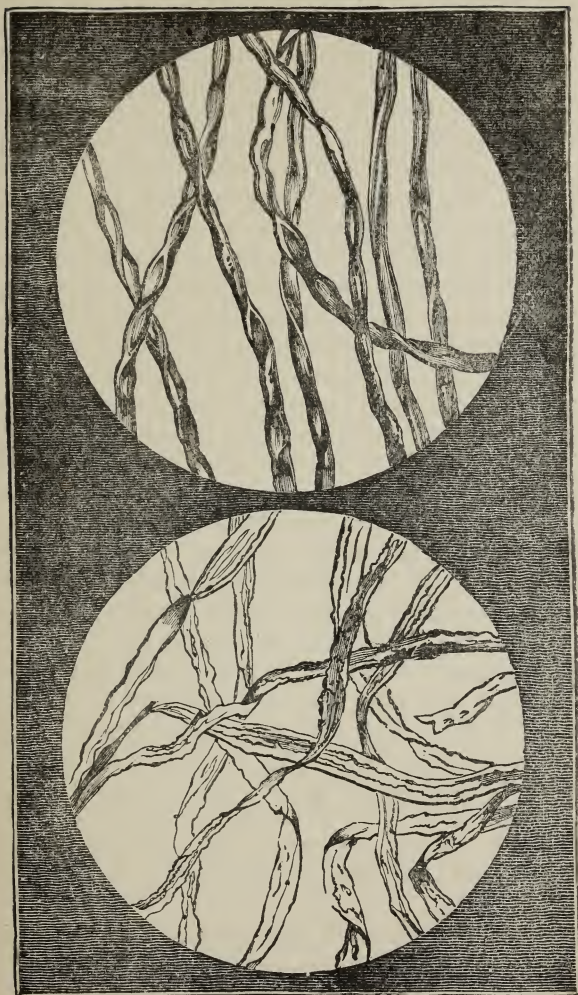


Fig. 7. Religious cotton.

to supply the requirements of domestic manufacture ; but these instances are diminishing in both number and extent, owing to the successful competition of European productions, chiefly English. The concentration of cotton-manufacturing in a few great centres has greatly stimulated the growth of cotton in a few localities where climate, soil, and circumstances are most favourable to its successful cultivation. The principal of these, in the order of their importance, are as follows—the southern portion of the United States, India, Egypt, and the Brazils. From these countries nearly all the cotton consumed for manufacturing purposes in Europe and America is obtained ; several other sources, such as the West India Islands, the West Coast of Africa, and Asia Minor, contribute a small quantity to the bulk. A large amount is produced in China, but this is almost, if not entirely, consumed in the native manufactures. Successful attempts have been made to grow cotton in Natal, New South Wales, and Queensland ; and should economic circumstances ever favour the cultivation of the plant in those regions, they will be capable of supplying a great portion of the world's needs.

In commerce, cottons are not designated by their scientific appellations, but by names derived from the districts or countries in which they are produced. Thus, “ Sea Island ” is chiefly grown on the small islands near the coast of Georgia and the Carolinas, and upon the coast line of the mainland. If this variety be cultivated further away from the sea, it rapidly deteriorates in quality. “ Uplands ” cotton is raised in the interior upon the higher lands of the States ; hence its name. Brazilian, West Indian, African, and Surats, are geographical adjectives, which sufficiently reveal the origin of the cottons to which they are applied.

In all countries cotton is generally grown upon the light loam or sandy soils, which, receiving and retaining the heat, whilst the substratum holds a good supply of moisture, force the plant into the most luxurious develop-

ment. In deep rich soils, it develops too much leaf and stalk. Cold damp clays are unsuitable for it.

The soil is prepared for the reception of seed by ploughing during the winter months; and sowing takes place in March, April, and May, according to countries and localities; the object being to avoid the exposure of the young plants to late frosts, which are extremely fatal to it. When thus caught, it is often necessary to replant the whole area. The fields having been prepared for the reception of seed, this, in some cases, is deposited in drills or furrows, at such distances apart as will allow space for the proper growth and healthy development of the plants. Five or six seeds are planted together, and afterwards thinned out as may be necessary. In other cases, holes are made in the soil with a stick or dibble, by men, and the seeds are deposited by women who follow them, whilst boys and girls come after with light hoes, and cover them up. The distance between the furrows is generally about six feet from centre to centre, the space being left sufficiently wide to allow the labourers to pass between during the picking season. Large areas are thus rapidly planted in favourable weather; when it is wet, the labour is much greater. Sowing finished, the efforts of the planter are directed to keeping his fields free from grass and weeds, which impoverish the soil, impede the growth of the plant, and diminish its product. Great care, and often labour, is required in the fields until the picking season, which commences in the latter part of July, and lasts until the frosts kill the plant, flowering and fruiting proceeding simultaneously until that occurs.

The picking season is the busy time on a cotton plantation. All hands are requisitioned, as the quality and cleanliness of the crop depends, to a large degree, upon its being quickly gathered after the bolls have opened. Should it be left on the plant long after opening, it is liable to be injured by the heat of the sun, which overdries it; or by

rains, which stain it; or, again, by winds which load it with sand, or dust and dirt of various kinds.

The cotton fields are so arranged that a section can be given to each picker, who, provided with a bag tied round his body, and a sheet or large basket, which he leaves at the end of his section, passes rapidly between the rows using both hands, picking the opened bolls on each side, until he gets to the end, when he empties the contents of his bag upon the sheet, and recommences his work. Picking is an operation requiring considerable skill and expertness. The picker has to seize at the first effort the whole of the cotton of each boll, and bring it away in his fingers, taking care also not to bring with it any of the boll leaf or petals, which is difficult to remove subsequently, and seriously deteriorates the quality. The average amount picked by each labourer in ordinary fields is about one hundred pounds of seed cotton per day, though here, as in all occupations, there are individuals who pick a weight considerably beyond this. The pickers go to the fields with the opening of day, and work, with little intermission for food or rest, until darkness closes in. Picking is a very unhealthy occupation in wet seasons, owing to the damp and rank undergrowth, which gives off, under the influence of the hot sun, heavy and noxious vapours, the cause of fevers, agues, and many other diseases. This description chiefly refers to the culture of American cotton, but it may also be accepted as typical of that of other countries.

The picked cotton is carried to the store-house of the plantation or farm, generally at the end of the day's labours, where it is kept until it can be ginned: that is, have the seed separated from the fibre. In the preparation of the finer qualities much more care is exercised than in the case of medium and low sorts.

The rapid extension of cotton cultivation in the American States has led to numerous attempts to invent a machine for gathering the crop. As yet these have not been successful, all revealing such defects in practical work-

ing as to prevent their adoption. The cotton crop at the present time is chiefly limited by the picking capacity, and should this difficulty be overcome by mechanical appliances, a revolution and extension of cultivation quite as great as that which followed the invention of the saw-gin may be expected to result, followed by a great reduction in price and increased consumption.

A brief glance may now be given at the specialities of the different fields of production, and their relative importance.

UNITED STATES.—The American cotton crop in amount probably exceeds that of all other countries put together. The cultivation of the cotton plant in that country has attained its present magnitude in less than a century, and is at present expanding more rapidly than at any previous time. The area of land laid under cotton was in 1881 estimated to be near 18,000,000 acres. In a favourable season this would represent a crop of 9,000,000 bales; in an unfavourable one only half this amount. Cotton cultivation in the States has not attained this great position without passing through numerous trials that in the hands of a less enterprising people would have destroyed it. In illustration, we may mention the great Civil War. The results of that struggle ending in the abolition of slavery have been important. Free and more intelligent labour is now employed; cotton planters, met by the energetic competition of northern immigrants, who are now in great numbers settling upon the cotton lands of the south-western States, are putting forth new energy. Better systems of cultivation have been introduced; fertilizers are extensively employed, and the production of lint per acre, which had fallen to an average of about 150 lbs., has during the past few years been steadily rising, and now reaches nearly 200 lbs.

Labour and the different materials necessary for raising cotton being articles of unstable value, the cost of production necessarily fluctuates with changes in them. This

cost has, however, recently been estimated for a farm of 150 acres exclusively devoted to raising cotton, as follows:—

Interest at 7 per cent. on value of land \$1,500	\$150.00
„ on value of four mules, implements, &c., \$550	38.50
Repairs of fencing at 13 cents per acre . .	19.50
Wages of one white foreman and manager .	200.00
„ „ three negro ploughmen	210.00
Provisions for four hands	100.00
Food for four mules (one year)	300.00
Salt and potash for manure @ \$1 per acre .	150.00
Twelve bushels of cotton seed for planting and manure per acre 1,800 @ 10 cents . .	180.00
Hire of eight extra hoe hands six weeks .	120.00
Extra labour for picking cotton	120.00
Toll of 1-15th for ginning	195.00
Taxes @ $1\frac{1}{4}$ per cent. on \$2,050	25.12
Aid for sundry incidental expenses . . .	100.00
Interest on outlay of \$1,700 @ 12 per cent. average time four months	68.00
Total expenses	<u>\$1,831.12</u>

As production varies all the way from 150 lbs. to 260 lbs. per acre, it will be safe to take a mean of these two amounts, or 205 lbs., which for 150 acres will give a yield of 30,750 lbs. at a cost of 5.95 cents per pound. Adding 75 cents for costs of transit, and other charges, from the interior to the ports, we obtain 6.70 cents, to which must be added 2.50 for commission, ocean transit, and landing charges at Liverpool, making the total cost laid down in that port equivalent to about $4\frac{5}{8}d.$ per pound, for a quality equal to average strict good ordinary. This estimate, however, does not take into consideration the profit derived from the sale of the seed, which, during the past few years,

owing to its having been extensively used for the extraction of oil, after which the meal that remains has been utilized for cattle feeding, has been very considerable. Assuming the product of lint or fibre to be 200 lbs. per acre, the cleaned seed will amount to 400 lbs., the proportion in ordinary years being two of seed to one of fibre; the yield, therefore, from 1,800 acres would be 320 tons of seed in addition to the fibre,¹ which must be added to the credit side of the above estimate.²

American cottons vary considerably in their characteristics and qualities. Being grown over a wide area, on different geological formations, at varying altitudes, on uplands with thin soils and a scant supply of moisture, and in river valleys with deep alluvial soils with abundance of water, there results the natural differences that might be expected from these conditions. There are wide variations in the length and diameter of the fibres; in the thickness of the walls and the number of the helical twistings. These differences are greatly increased when comparison is made between cottons grown on plantations or farms some distance apart. Also the system of cultivation pursued has an important effect on the quality of the crop. Where the grower trusts entirely to the natural fertility of the soil, especially in the older settled lands, the quality of his product will compare badly with that of his neighbour using fertilizers. Those persons whose experience in using American cotton extends beyond the period of the Civil War and the destruction of slavery, will remember the greater uniformity of American cottons at that time. Then it was possible to purchase repeatedly from the production of one plantation, where a large number of bales

¹ The oil mills pay for seed delivered at a railway station or river landing \$12 per ton, and as in the preceding estimate the cost of seed has been included, the above may be reckoned available for sale, yielding \$3,640.

² Not more than one-fourth of the seed available is yet utilized in this manner.

had been grown under identical conditions, which ensured uniformity of quality.

Since the fall of slavery and the decay of the plantation system, cotton growing has passed into the hands of small capitalists and farmers who cultivate the plant as their intelligence and necessities may dictate, which is too often in an ignorant and unscientific manner. These farms are scattered on the banks of navigable streams, by the side of railways, or near highways, in order to secure facilities of transit. Their owners send their seed cotton to gin-houses in the neighbourhood, where but little care is exercised to keep the lots separate. Here good, bad, and indifferently grown cotton is often mixed together to the depreciation of the bulk. Cotton is not usually baled either at the gin-houses or on the farms, but is packed loosely in bags. These are purchased by dealers who travel the country for the purpose, and are collected and sold to another class of dealers called factors, possessing baling establishments with presses, and who are found both at the interior towns and the ports. Here the cotton gathered from so many sources ought to be carefully classified or graded before baling, but this is too often negligently performed. Hence arise the frequent complaints of cotton-spinners about false packing, several qualities often being found in one bale. The current crop (1882-3) is much complained of, on account of excessive dampness, which there is too much reason to suppose has been artificially introduced.

In these establishments there has also sprung up of late years a vicious system of adulteration, in which a great deal of rubbish is wilfully introduced into the bale. The natural variation of the fibre, careless packing and fraudulent mixtures, render the task of the cotton buyer exceedingly difficult, and one which requires the most experienced circumspection and careful discrimination if an even quality of yarn has to be produced from its use. It is no longer safe to entrust the mixing

of American cottons to mill labourers, but it is almost indispensable that the buyer or some qualified person be present to watch the unpacking of each bale in order to prevent a low quality of fibre finding its way into a "mixing" intended to spin a good yarn. Owing to uneven growth, irregularity of twisting, and varying diameter of fibres, the latter do not combine so closely in spinning as does Egyptian, in which these qualities are more uniform; hence a soft, bulky, and comparatively weak yarn is produced. Notwithstanding these serious defects, American cottons constitute the most important part of the world's supply, being used for the production of the middle numbers of yarn, which form by far the greatest portion of that required.

WEST INDIES.—During the last century England obtained its chief supplies of raw cotton from these countries. The variety grown was called *Anguilla*, which was similar to the present Sea Island, and from which the latter is said to have been derived. The increased production of sugar and the abolition of slavery caused the cultivation of cotton greatly to decline, and at present the total production is small.

CENTRAL AND SOUTH AMERICA.—Nearly all the countries embraced under this heading lie within the cotton zone, and are capable of growing it in abundance, and of good quality; but the political disorganization that seems a chronic condition of most of them has prevented the development of its cultivation to the extent that might have been expected in view of the great market existing for the crop in Europe. During the Civil War in the United States considerable numbers of cotton planters emigrated to these countries, and the production rose considerably. Of late years, however, most of these have returned to the States, and it has again declined nearly to its former level. It is not probable that under ordinary conditions these countries will ever become formidable competitors with the United States.

An indigenous species of cotton, the *G. Peruvianum*, is extensively grown throughout the countries under notice. It is arborescent, the plant attaining an altitude of from ten to fifteen feet. It yields good crops for several years in succession, and is renewed only about once in ten years. In the mountain districts of the Andes it bears fruit until the advent of snow and frost. The cottons known in the market as Pernams, Maranhams, &c., are obtained from this species. In Brazil the Orleans variety has been introduced and extensively cultivated, and, as modified by the change of locality, the product appears in the market as "Santos." The remainder of the Brazilian and Peruvian varieties as known to commerce are simply described by geographical adjectives, and are derived from either the arborescent species or the imported variety. The former are harsh and wiry in staple, and the latter soft, like the American kinds from which they spring.

EGYPT.—The most important cotton producing country on the African continent is Egypt. Though the indigenous variety has been known and cultivated for centuries, it is only since 1820, when the Brazilian species was introduced, that the cultivation of cotton has been systematically pursued, and has become an important industry. The climate and soil is exceedingly favourable, and the qualities of the staple are of the highest order. The chief difficulty encountered is the deficiency of labour, which greatly impedes the extension of its growth. The crop is generally equal to 400,000-500,000 bales of 400 lbs., and has on one exceptionally favourable season attained nearly 800,000 bales. Two or three varieties of exotic cottons are grown; that from Sea Island seed, or the *G. Barbadosense*; the South American, *G. Peruvianum*; and *G. hirsutum*. The first named does not produce a staple quite so good as when grown in its original habitat. These yield the white varieties of Egyptian cottons, and in several respects fall short of the best qualities of the thoroughly acclimated sorts.

The chief characteristics of Egyptian cottons are the length, strength, and uniformity of their fibres, showing great equality of growth, probably arising from the remarkable freedom of the country from extreme changes of temperature. In these cottons, however, there occurs a varying quantity of short, hairy, or undeveloped, fibres. This defective staple is found most abundantly in seasons when the Nile has not risen to its usual height, and the plant has therefore been deprived of a sufficiency of moisture to secure full development. The opposite condition arises when the overflow has been extensive, as then both a greater quantity and higher quality are secured.

INDIA.—Since the cotton famine in this country, the result of the American Civil War, India has formed an important source of cotton supply. The native varieties nearly all belong to the *G. herbaceum*, and have been cultivated for thousands of years for domestic consumption, and to a limited extent for export. The great demand, and the high price which prevailed for several years owing to the above-named event, strongly stimulated production and led to an improvement of the quality. The rate of progress, however, has not been fully maintained.

The cottons of India are commercially known as Surats, and are generally, like most others, characterized by the names of the localities in which they are produced. The best known are the Dharwar, Broach, Oomrawuttee, Dholera, and Hingunghat. The last is the best quality, and is grown in the Central Provinces and the Berars. Exotic cottons have not been very successfully cultivated, and efforts have therefore recently been directed to improve the indigenous kinds.

OTHER COUNTRIES OF ASIA yield cotton to a more or less extent, but beyond sufficing for local wants the growth is not of much importance. A brief enumeration of the distinctive features of these growths will, therefore, be all that it is necessary to give in this place.

China produces a large quantity of cotton, but rarely

exports any. During the cotton famine a fair quantity was sent to England of a fine white clean cotton, not very strong in staple, and therefore best suited for wefts, for which it was mostly consumed. Nankin cotton is a variety of the *G. herbaceum*.

In Japan, Java, and several other islands in that locality, an inferior kind of cotton is grown, which is mostly consumed in the same places.

Bokhara and Turkestan in Central Asia produce annually about 1,000,000 cwts. of a coarse description of cotton, most of which is carried overland to Russia. In East Turkestan a better quality is grown, which is capable of taking the place of American. By stimulating the cultivation of cotton in that district, it is said that Russia hopes to establish her independence of external sources of supply. Soil and climate are favourable; the plant attains a height of nine feet, and is moderately prolific.

The Asiatic portions of the Turkish empire produce a fair amount of cotton, but with proper enterprise this could easily be increased five or ten fold. It is most successfully cultivated in the neighbourhood of Smyrna. The yield of these districts amounts to about 75,000 bales annually, which is mostly exported to the countries of southern Europe. The varieties are chiefly those of the *G. herbaceum*.

Syria and Persia are capable of producing a fair quality of cotton. The latter country grows a considerable quantity, and the export has formerly, on occasions, amounted to as much as 100,000 bales.

Cyprus yields cotton of fair staple, and with the introduction of enterprise and capital, might very largely augment its crop. It is grown in the districts of Larnaka, Famagusta, Karpas, Lefka, and Kythrea. An average crop at present does not exceed 2,500 bales.

EUROPE.—In Europe the countries bordering the Mediterranean sea are the only ones capable of producing cotton. Turkey, Greece, Italy, and Spain are all possible fields of

culture, but the first three only utilize their capabilities. In 1864, American seed was introduced into Italy, and under the stimulus of high prices over 200,000 acres were planted, the crop attaining a total of over 300,000 bales. It is at present cultivated around Bari and Barletta on the Adriatic, and in the districts of Salerno, Laron, Castellamare, south of Naples ; and in several places on the shores of Sicily. The products are known in the markets as Pugliar, Castellamare, Biancaville, and Terranova. A small quantity is also grown in Sardinia.

This completes a brief view of the sources of production that may be regarded as of commercial importance.

As may readily be inferred, cotton from over this wide area will differ considerably in its characteristics according to the species and varieties cultivated, and the climate, soil, and other circumstances. The best staple is produced on the light sandy alluvial soils of river valleys, where moisture is rarely deficient, and in which the plant can send its tap root down to and reach the supply in the driest seasons. These conditions are highly conducive to uniform growth of fibre in length and diameter, and consequently of its convolute twistings. Thin soils and deficient and irregular supplies of moisture interrupt the growth and regular development of the fibre, and so produce an inferior staple, irregular in its length, diameter and twistings, not only when one fibre is compared with another, but in the latter qualities even in the length of individual fibres. Sea Islands and Egyptian cottons are the most uniform and perfectly developed staples, because grown under the most equable conditions. American varieties came next, and Indian cottons last in these respects. Of course all these conditions can be modified by careful cultivation and artificial aids to nature, especially by manuring and irrigation, which, however, enhance the cost of production.

As the climate of a district or country is, comparatively speaking, a fixed element, having an ascertained range of variation, the differences in the quality of the product

within a given limit will also be known. Hence it will be obvious that the geographical designations given to cottons are the best and most useful that could be devised, because they afford a clue to the most important circumstances of its production. The species of cotton cultivated, the natural conditions surrounding it, the systems followed by the growers, and the care and conscientiousness, or the absence of these qualities, bestowed on the cultivation are, in a general manner, revealed by the name of the country in which the cotton has been produced. If we could wish for any change in this respect it would be for its further elaboration, in order to describe more definitely the locality of growth, whether valley or upland, as this would still further help the buyer to secure a uniformly grown staple. In some American qualities this is done. The following tabular form exhibits these characteristics in detail in the most important cottons of commerce :—

Country of Growth.	Name.	Districts where grown.	Species.	Length of staple in inches.			Mean diameter of fibre.	Description.	Capabilities and uses.
North America	Sea Islands	Islands on coasts of Georgia and Florida	G. Barbadosense	1·80	1·60	1·70	1 1/16 5/12	A fine silky regular cotton, of several varieties, American being best.	Suitable for the finest yarns that are produced. Has been spun to over 2,000s.
	Florida ditto	Florida Mainland	"	1·85	1·30	1·58	"		
	Upland	Georgia and South Carolina	G. hirsutum	1·20	1·00	1·10	1 1/16 9/10	Soft and rather short in staple; usually clean; best adapted for wet.	These qualities may be spun up to 60s. when used alone, but are greatly improved for the higher counts by admixture with Brazilian or Egyptian.
	Mobile	Alabama and adjacent States	"	1·20	·90	1·05	"		
	Texas	State of Texas	"	1·00	·70	·85	"	Firmer in staple than above, but contains more leaf, and is less bright in appearance.	
	"	"	"	·95	·70	·82	"		
	Orleans	Mississippi and Louisiana	"	1·20	1·00	1·10	"	The best and most regular of all the American cottons. Some lots are very white, but leafy; others of a creamy tint, but clean.	
	Pernams	Pernambuco	G. Peruvianum	1·50	1·20	1·35	1 1/16 6/5		
	"	"	"	1·40	1·10	1·25	"	These are Brazilian cottons, with one exception grown from the indigenous arborescent species, G. Peruvianum. As a rule they are harsh to the feel, and give a wiry nature to the yarns into which they enter. Santos is an exotic introduced from the United States.	May be used alone or mixed with American or Egyptian, and will make good yarns up to 60s. or 70s. counts.
	Ceara, Aracati, &c. Paraiba	North coast of Brazil	"	1·30	·90	1·10	"		
South America		Eastern coast of ditto	"	1·30	1·10	1·20	"		
	Santos	Brazil	G. hirsutum	...	...	...	...
	Bahia	San Salvador	G. Peruvianum	...	...	...	...
	Aracaju, &c. Maceo	"	"	...	...	...	...
		Eastern coast of Brazil	"	1·30	1·10	1·20	"		
	Maranhams	Coast of Brazil	"	1·30	1·00	1·15	"		
	"	"	"	1·30	·90	1·10	"		

Country of Growth.	Name.	Districts where grown.	Species.	Length of staple in inches.			Mean diameter of fibre.	Description.	Capabilities and uses.
				Max.	Min.	Mean.			
Egypt	Gallini, Egyptian Brown	Messifieh, &c.	G. Barbadense	1.60	1.40	1.50	1526	Sea Island variety.	Will spin up to 200s.
	White	Zagazig, Mansurah, Beharah, &c. Ziftah, &c.	G. herbaceum	1.50	1.20	1.35	...	Indigenous, soft, and silky.	" " 140s.
			G. hirsutum and Peruvianum	1.40	1.10	1.25	...	Exotics, hard and rather harsh.	" " 80s.
Levant Greek Islands	Smyrna Greek, &c.	Levant Greek Islands	G. herbaceum	...	...	1.24	...	Harsh in staple and characterized by its irregularly twisted fibres.	" " 80s.
Polynesia	Fiji, sea island	Polynesian Islands	G. Barbadense	1.90	1.25	1.70	...	Very irregular in staple.	Fine counts as in Sea Islands, but not so high.
	Tahiti, " West Indian	"	"	"	"	"	...	Fair in staple, but cannot be relied upon through successive seasons for uniformity in colour.	Alone and mixed with American and Egyptian up to 60s.
West Indies	"	West Indian Islands	G. Peruvianum	1.60	1.30	1.45	...	Fair in staple.	Up to 60s. alone or with Egyptian or American.
	"	"	"	1.40	1.20	1.30	...	Fair in staple.	Fine counts.
South America	Haytien Laguanayan	St. Domingo Venezuela	"	1.40	1.20	1.30	...	Exotic, Fair.	Up to 60s. as Haytien.
	" sea island Peruvian, rough	" Peru	G. Barbadense	1.80	1.45	1.70	...	The soft assimilates best with Orleans; the hard is best mixed with Brazilian.	"
	Peruvian, soft staple	"	G. Peruvianum	1.40	1.20	1.30	...	Exotic, Fair.	"
	Peruvian, sea island	"	G. Barbadense	1.50	1.30	1.40	...	Exotic, Fair.	Fine counts.

Country of Growth.	Name.	Districts where grown.	Species.	Length of staple in inches.			Mean diameter of fibre.	Description.	Capabilities and uses.
				Max.	Min.	Mean.			
India	Hingunghât	Central Provinces	G. herbaceum	1.40	1.00	1.20	$\frac{1}{1360}$	The various classes ranged under the general head of Surats are fair working cottons, but the fibres are neither so uniform in length, diameter, or twisting as in American cottons. Many of them are brighter than American.	These cottons cannot be advantageously be used alone for numbers above 28s. or 30s., but in conjunction with American are available up to 40s., and slightly higher for wuffs. Exotic varieties can be used for higher numbers.
	Dharwar	Bombay Presidency	"	.90	1.10	1.00	$\frac{1}{1185}$		
	Broach	"	"	...	...	.90	"
	Dholerah	Bombay Feudatories	"	...	...	1.10	"
	Oomrawuttee	Central Provinces	"	...	...	1.00	"
	Veravul	"	"	...	...	.95	"
	Comptah	"	"	...	...	1.05	"
	Scinde	" Indus Valley of	"	...	...	1.00	"
	Bengal	Presidency of Bengal	"	...	...	1.10	"
	Rangoon	British Burmah	"	...	...	.85	"
	Tinnevelly	Presidency of Madras	"	...	...	.95	"
	Western	" Natal	"	...	...	1.00	"
	African	West Coast, &c.	Liberia	...	...	1.25	"
			West Coast	...	...	1.00	"
				...	...	.90	"
								As Surats.	As above.

The details embodied in the foregoing table will, in combination with the practical experience indispensably necessary to safe operations in cotton buying, form a useful guide to the selection of the class of cotton that may be desired for any purpose.

Cotton is assorted into classes or qualities to suit it for different uses, and to meet the wants of consumers in the most economical manner. It is a leading principle in spinning and manufacturing, and one that should never be lost sight of, that the material employed for the production of any kind of yarn should be of a quality sufficiently good to make a satisfactory article without risk of failure; but that it should not be better, as all the quality above that requisite is wasted; on the other hand, it should never fall below the standard of requirement, as in that event the loss on depreciation of quality would considerably exceed any gain from the lower price of the raw material. This is the principle underlying the classification of cottons. The qualities chiefly considered in making the assortment are: length of staple, fineness, strength, colour, smoothness, and cleanliness.

The cottons produced in the United States are generally divided into four classes: good ordinary, low middling, middling, and good middling; and these again into several subdivisions. South American sorts form three: middling fair, good fair, and good. Egyptian two: fair, and good fair. East Indian three: fair, good fair, and good. The Liverpool Cotton Brokers' Association possesses standard samples of these classifications to which reference is made in case of dispute as to correct classification. The brokers individually form a set of reference samples by comparison with the official standards of the sorts of cotton in which they deal. This is for the purpose of ready comparison when circumstances call for such a step.

Scarcely two cotton crops, however, are alike in point of quality, and consequently the standard samples are subject to variation. According to the relative abundance,

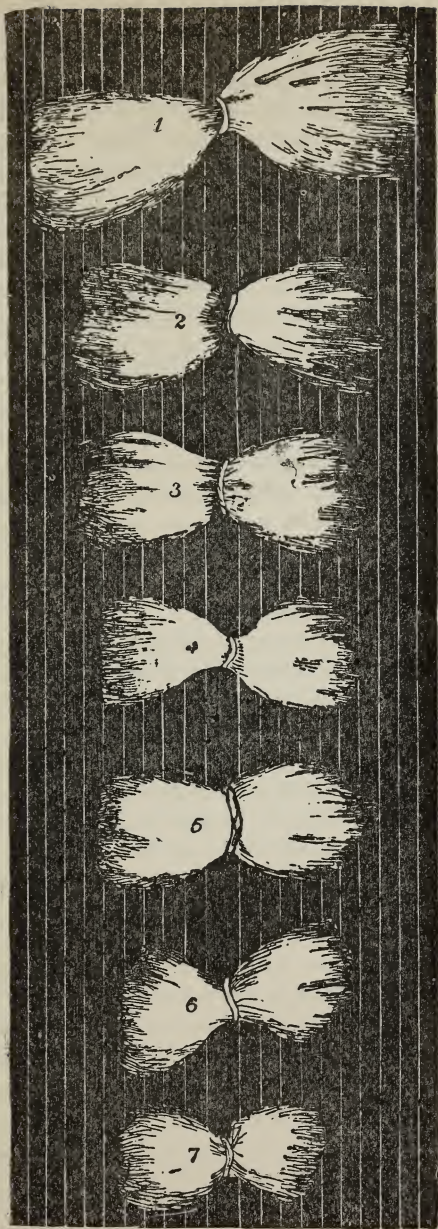


Fig. 8.

scarcity, fulness, or deficiency of particular characteristics, the different grades are classed up or down from the official standard as the cases may require. Thus, within a limited range, there is a constant fluctuation of the standard.

The preceding illustration (Fig. 8) will perhaps convey a more definite idea of the length of staple in several representative varieties than can be gathered from a verbal description, or details in figures :—No. 1 represents Sea Island, mean length of staple, 1.65 in. ; 2, Egyptian, 1.50 in. ; 3, Pernambuco, 1.25 in. ; 4, American, 1.10 in. ; 5, Port Natal, 1.10 in. ; 6, Indian, 0.90 in. ; 7, Indian, 0.65 in. The number of these could be largely increased, but the above specimens will be adequate for the purpose in view.

Practical skill and high discriminative power are needed to select cotton of the proper quality to make any particular description of yarn, and these ought to be carefully exercised in the operation of buying, as mistakes cannot have their consequences entirely eliminated after the cotton has passed into consumption.

THE MECHANICAL STRUCTURE OF THE COTTON FIBRE.—Of the various species of cotton, the *G. herbaceum* is the most widely distributed, and yields the greatest portion of our supply. As such, it may be accepted as the representative plant of the genus. It constitutes a small shrubby bush, when mature being about the height of a man. Sown in March, April, and May, it begins to bloom in June and July, fruiting towards the close of the latter month, and usually continues to bear fruit until killed by the frost. The flowers are generally yellow, though a few varieties have them of a reddish or purplish hue. The pod is pendent from the branches by a small stalk, through which nutrition from the plant is conveyed. The following illustrations, Figs. 9 and 10, and description from the recently published monograph of Dr. Bowman of Halifax, an accomplished scientific inquirer and practical cotton spinner, conveys a good idea of the cotton pod and the development of the fibre.

Fig. 9. Longitudinal section of cotton pod.

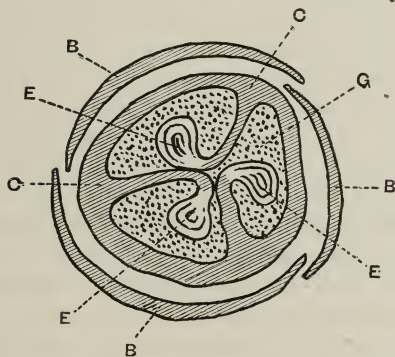
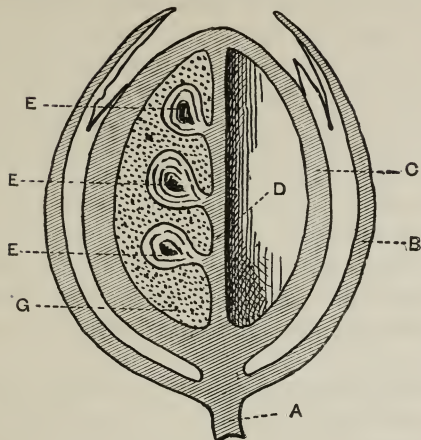


Fig. 10. Transverse section of cotton pod.

The above figures represent longitudinal and transverse sections of the Egyptian cotton pod. In each case the letters refer to the same parts: A, stem; B, section of calyx; C, section of carpel; D, midweb, with seeds attached; E, section of seeds; G, plexus of young cotton fibres.

“If we examine a cotton pod in the earlier stages of its growth, we find, Fig. 9, that it is attached to the stem, A,

of the parent tree by a small stalk. Immediately below the pod itself we have a ring of leaves, four or five in number, forming what botanists call a *polysepalous calyx*, and between which and the seed vessel itself there are the withered petals of the corolla which formed the coloured part of the flower of the tree. The pod or capsule itself is the developed ovary, and consists of a hard outward sheath, which is divided longitudinally into a series of valves, differing in number in the different varieties of cotton (usually three in Egyptian and four or more in American). These valves have each a rib or septum projecting inward from the inner surface, and dividing the capsule into separate compartments, in which the seeds are confined.

“In the earlier stages of growth the seeds appear to be attached to the inner margin of the carpillary septa at the point of junction of these septa, that is to say, at the inner side of the carpel, where the two edges of the carpillary septa unite, and they are connected to it by vascular bundles, which proceed from below upwards, traverse the carpels, and send a branch to each seed. At the same time there is also a considerable development of cellular tissue, forming a ridge or placenta on the margins of the septa to which the seeds are attached. The seeds continue this attachment until they have attained their full size and the growth of the hair on the surface of the seed has commenced. It then becomes gradually absorbed, and the seeds themselves are forced into the centres of the cavities by the gradual development of the hairy covering. The structure of the cotton pod will be readily understood by a reference to the annexed drawings, where, in Fig. 9, we have a longitudinal, and in Fig. 10 a transverse section of an Egyptian cotton-pod. Here the seed vessel or carpel is divided into three separate compartments, each containing a lock of cotton surrounding the seeds which are contained in them. The method of growth of the seed appears to be like that of a nut, viz., by the successive deposit of

concentric layers on the inner surface of the outer envelope. In a growing seed these successive layers are distinctly visible even to the naked eye when the seeds are cut in two, the layers growing less dense as we proceed inwards, until we come to the oleaginous milky fluid which fills the centre cavity, and which gets smaller and smaller as the stage of maturity is reached. The development of hair commences at the further end of the seed from its point of attachment, and gradually spreads over the surface as the process of growth continues.

“The first appearance of the cotton fibre itself occurs a considerable time before the seed has attained its final growth, and commences by the successive development of cells from the surface of the seed. These cells appear to have their origin in the second layer of cellular tissue, and force themselves up through the epidermal layer itself, making good their attachment by the gradual absorption of the cell walls of the outer layer, which they displace and form a larger cell, out of which the linear propagation of cells commence. This point, however, needs further investigation, as, unfortunately, I have had few opportunities of watching the method of growth in its earlier stages.

“These germinal cells are distinguished in their earlier stages by the thickness of the cell wall in proportion to the diameter of the cell, and the method of growth is by the successive linear development of cells, the cell wall at the point of junction being gradually absorbed until an exceedingly elongated cell is produced, which constitutes the cotton fibre. During this period of growth the cell walls are continually becoming more and more attenuated, and gradually fill up the seed pod with an apparently tangled plexus of young cotton fibres, whose growth and increase in the number of fibres as the seed continues to throw them off tend to assist in bursting open the seed pod when the time of maturity arrives.

“The length of the hairs varies considerably on different

parts of the seed, and indeed it appears doubtful whether they ever attain their full length until after the pod has fully opened, and the fibres themselves have been exposed to the drying and ripening effect of air and sun. As a rule the longest fibres are those which have grown on the crown of the seed where the cell development makes its earliest appearance, and the shortest are always found at the base of the seed."

The foregoing constitutes a very clear and interesting description of the cotton pod, the arrangement of the seed, and the development of the fibre. Some of the conclusions, however, appear open to question. The description of the development of fibre from germinal cells in the dermis of the seed, and which in this respect is remarkably similar to the growth of hair and wool in animals, the statement of the method of growth by the successive linear development of cells at the apex of the fibre, and the description of the absorption of the dividing walls at the point of contact so as to form one exceedingly elongated cell, constituting the cotton fibre, are doubtlessly quite correct, but it may be permitted respectfully to differ from Dr. Bowman in regard to his description of the concurrent and succeeding phenomena of growth. It seems highly probable that the elongated cell walls do not undergo attenuation as the length of the fibre increases, but the opposite; length and diameter increasing together in all but exceptional and abnormal instances. It is more likely that whilst growth is progressing the fibre preserves a hollow cylindrical form, in which the vital fluids of the plant circulate, conveying to each part the material necessary for growth and perfect development. In this process the cylinder walls are constantly growing in thickness by the deposition of material on their inner surfaces. When maturity has been attained, and the seeds are ready for casting, the vital fluids cease to be secreted and consequently are no longer supplied to the fibres. That which the latter contain is either absorbed by the seed or dispersed by dessica-

tion—we incline to believe the former, the effect being that a vacuum is formed in the hollow of the fibre. This absorption of the fluid is not instantaneous, but extends probably over several, say two or three, days. The apex extremity of the fibre is a cone of what may be called almost solid cellulose, which nearer the base gradually opens into the tubular form, which is continued to the junction of the fibre with the seed. As the circulatory fluids are withdrawn, the vacuum is formed in the tube at the point nearest to the extremity of the fibre, and at which it begins to collapse owing to the pressure of the atmosphere, the process closely following the retreating fluid down the length of the cylinder to its base in the seed. The consequence is that the free end of the fibre is twisted on its own axis a considerable number of times, and as this is going on simultaneously in almost every fibre of one pod, the primary order of arrangement is disturbed to such an extent that the carpel is burst open and the mass of fibres is exposed to the dessicating influence of the sun's rays, which quickly completes the process. The form of the fibre has now been changed from the hollow cylinder maintained during growth to that with which we are most familiar, a twisted ribbon-like figure having corded edges. This corded form of the edges is caused simply by the bending of the fibre walls upon themselves in the action of collapsing and is a necessity of a properly developed fibre. Such the writer believes is the normal process of development in the cotton fibre, which results in a mechanical configuration that admirably fits it for the purpose which nature designed, namely, the dispersion of the seed, and also for the use to which it has been converted by man.

Against this theory it may be urged that in all pods of cotton short, immature, or undeveloped fibres are always to be found. In reply to this it will be sufficient to point out that growth does not commence in all the fibres of one pod, or indeed of one seed, simultaneously; hence all do not reach maturity at the same moment; neither are all

the germinal cells of the fibres equally vigorous in secretive or circulative power: hence both length and diameter of fibres may differ considerably. Neither does the safety nor natural propagation of the seed require that all the fibres of each seed should be perfectly developed; it is sufficient for natural requirements if they form a loose flossy mass presenting a great surface with little weight to the action of the winds, which, if not interfered with, would carry them far and wide in the locality of their growth. In some instances very thin transparent and flat fibres are present: possibly owing to the reproductive power of the cells operating in all their force whilst the circulation of the vital fluid is weak, impeded, or entirely obstructed. These undeveloped walls may collapse without producing a single convolution of the fibre; hence the ribbon-like, transparent, and apparently structureless character of these fibres.

The mechanical structure of the cotton fibre, as the writer has observed in another place, is such that its perfect development has an important bearing upon its quality. As received in this country mature or ripe cotton fibres when placed under the microscope present the appearance of irregularly twisted ribbons with thick rounded edges. The thickest part is the root end, or base, that which was attached to the seed. The diameter of the cylinder remains without material change through, probably, three-fourths of its length, after which it more rapidly tapers to a point. The accompanying illustrations admit of a comparison of the fibres of cotton at different stages of growth or development. Figs. 11 and 14 exhibit a portion of mature fibre and sections magnified. The latter show it to be a collapsed cylinder, the walls as compared with the bore being of considerable thickness. The one or two exceptions to this form are probably instances in which the cylindrical form has been ruptured. Fibres possessing these characteristics are considered well developed, being the longest and strongest. But amongst the perfect fibre there is always

more or less of unripe, imperfectly developed, or dead fibre, this being less or more accordingly as the surroundings have been favourable or unfavourable during the period of



Fig. 11.



Fig. 12.



Fig. 13.



Fig. 14.



Fig. 15.



Fig. 16.

growth. In commercial cottons, especially of the lower grades, the proportion of defective fibre is always largely increased by the practice common, if not general, amongst cotton growers of collecting the immature pods on the cotton

plant after the latter has been killed by frost, or from exhaustion of their vital power have ceased to grow. These are dried and the lint stripped from them, which is added to the bulk. The appearance of the unripe fibre is very different, both longitudinally and in section, from that which is mature. In Figs. 12 and 15 the half ripe fibre is shown longitudinally and in section. In this case the ribbon is flatter, the twists are fewer, and the thickness of the corded edges is diminished. The sections show the collapse of the tube to be so complete as almost to destroy all trace of the original cylindrical form. The least ripe fibres that appear in commercial cottons are illustrated in Figs. 13 and 16. The twisting is further diminished, and the corded edge disappears altogether. The internal surfaces adhere so closely that the hollow is quite lost, and the sections appear like crooked bits of fine wire. This is owing to the deficient quantity of the cellulose deposited. These fibres are thin, brittle and weak, and incapable of taking dye-stuffs in dyeing and printing.

Occasionally these defective fibres are found in greater abundance than at other times, and more frequently in irregularly grown cottons, or the cottons of those countries where the plant is apt to suffer from a deficiency of moisture, as in Indian cottons. When abundantly present they greatly depreciate the working qualities of the bulk, and it is an important matter in judging of cotton to be able to distinguish them. This ability may be acquired by careful observation, and in this the natural sight may be beneficially aided by a powerful lens.

The mechanical structure of cotton fibres, especially in having a convolute form and corded edges, peculiarly adapt them for numerous uses. If they were cylindrical like the fibres of flax and hemp, they would be too short to hold together when spun into a thread. When the proper structure is fully developed, in the twisting process they become firmly bound together, one fibre folding over and gripping the corded edge of another, thereby enabling a con-

tinuous thread of considerable strength to be made. When the finest and longest stapled varieties of cotton are used, this thread is capable of great attenuation. Cotton gathered from the unopened pod does not possess the perfect convolute form in the fibre; and, as seen in the illustrations, fibres that from other causes are imperfectly developed come in the same category: hence do not possess the same cohesive power when spun into yarn. When present to any appreciable extent they are the cause of serious defects when the yarn or cloth containing them has to be dyed or printed. The convolutions in Egyptian and American cottons are more regular and the development more perfect than in other descriptions, which fully accounts for the acknowledged superiority of these varieties. The naked eye is incapable of distinguishing these twistings, but the microscope shows them to amount to from one hundred to three hundred an inch, and closer investigation would probably show a wider variation than even this.

It will interest the reader to have placed before him the results of some very recent researches into the structure of the cotton fibre. These have been conducted by Mr. John Butterworth of Shaw, and were first made public in a paper read before the Oldham Microscopical Society, on April 10th in the current year (1883), and communicated to the present writer for publication in the "Textile Manufacturer." In the year 1863 Mr. Charles O'Neil of Manchester, well known as a writer on tinctorial matters, had been conducting some researches in connection with the cotton fibre and its behaviour under certain chemical agents. In employing Schweitzer's solution (an ammoniacal solution of oxide of copper) for dissolving cotton and other forms of cellulose, he made numerous experiments upon the former, watching its action upon the fibre by means of the microscope. In the course of these he thought he could discern four distinct parts of the fibre—1st, the outside membrane, which did not dissolve in the solution; 2nd, the real cellulose beneath, which dissolved, first swel-

ling out enormously and dilating the outside membrane ; 3rd, spiral fibres, apparently situated in or close to the outside membrane, not readily soluble in the copper liquid, and which were not so elastic as the matter of the outside membrane, and acting as strictures upon it ; these produced bead-like swellings of a most interesting appearance ; and 4th, an insoluble matter occupying the core of the cotton hair, which very much resembled the shrivelled matter in the interior of quills prepared for making pens. Mr. O'Neil noted at the same time that the outside membrane, which was insoluble in the menstruum and impermeable to it, could not be found on cotton which had been submitted to the usual bleaching process. It had been dissolved away, or, what seemed more probable, some protecting resinous varnish had been removed, and then it became soluble. These conclusions of Mr. O'Neil were questioned some time afterwards by Mr. Dancer, an eminent microscopist of Manchester, who repeated Mr. O'Neil's experiments, and saw what he saw, but concluded that the spirals seen did not exist in the cotton fibre, but were formed by the rotating or twisting of the hair under the influence of the solvent. The disputed point has, however, recently been further investigated and authoritatively set at rest by the researches of Mr. Butterworth, who has strongly confirmed the conclusions of Mr. O'Neil. Mr. Butterworth carefully observed the behaviour of the fibre while under the influence of the solvent, with various powers ranging from 100 to 1,600 diameters, and saw it clearly as represented in (1) of the annexed illustration, Fig. 17. The longitudinal stria were scarcely perceptible at from 300 to 400 diameters. Though the Fig. at D may be slightly overdrawn, the spiral threads were clearly seen apparently crossing in the manner shown, as well as being tightly bound round the fibre at irregular distances, c forming the bead-like swelling referred to by Mr. O'Neil. If the solution is strong, this swelling of the cellulose is performed so rapidly, as to burst these bands, and the field of

the microscope becomes covered with them in broken circles. If the solution be only of moderate strength, the swelling of the cellulose goes on slowly, and its striated appearance comes into view beautifully. When strictures occur near the end of the fibre the cellulose protrudes from the end, forming a fan-like appearance, yet retaining its striated character, as shown at A. The spiral threads are often seen passing from one stricture to another, as shown at B, and under a high power it can be seen that the

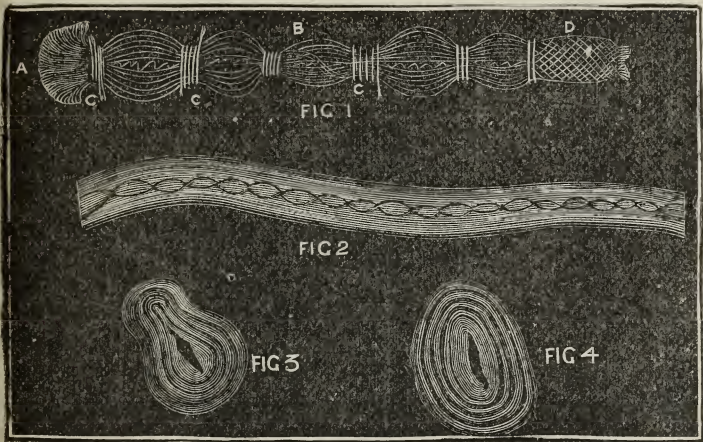


Fig. 17. Magnified view of cotton fibre.

rapid swelling of the cellulose has burst them asunder, the ends of each thread showing that they have been torn violently apart, as seen at c. In some instances the solution is not powerful enough to throw the cellulose into the bead-like form, but it takes out the natural twist and gives it a cylindrical form. Under these circumstances the core of the fibre can be seen having the spiral form, as shown in 2. Seen in transverse section, the fibres take the appearance of concentric rings, 3 and 4, a state in which they have been recorded by Mr. Walter Crum, an

eminent calico printer of Manchester. In referring to the waxy covering of the fibre which is removed by bleaching, Mr. Butterworth stated his belief that its scanty or abundant presence would be found materially to affect the working capabilities of cottons; also that as long as it is present a perfect bleach cannot be obtained.

The above is a condensed statement of Mr. Butterworth's views upon this interesting subject. The illustration, however, reveals a few additional points and suggests some further thoughts. The structure of a fibre of cotton is shown by these drawings to be exceedingly complex, and it may fairly be inferred that all is even not yet known. The function or purpose of these curious threads appears to be to impart strength to the tube or fibre, to preserve it from rupture during the period of growth, when the vital circulation of fibre is most active, and the deposited cellulose least consolidated. It may be safely assumed that the core of the fibre showing a spiral form consists of the cellulose held in suspension in the circulating fluid, at the moment circulation and deposition ceases, which is when maturity is attained. The absorption and dessication of the fluid leaves the solid cellulose behind in a thin shrivelled film precisely as pointed out by Mr. O'Neil in the analogous phenomenon seen in a dried quill. The transverse sections, 3 and 4, are exceedingly instructive, and appear to fully substantiate the argument laid down a few pages back relating to the phenomenon of growth. The concentric circles prove that growth is orderly and progressive, while at the same time it is liable to be affected by external conditions. Were growth perfectly steady and at a uniform rate, the deposit of cellulose upon the internal surface of the fibre would be continuous, and would not show the laminated form seen in these cases. These divisions register, in all probability, periods of interrupted growth arising from atmospheric changes, such as falls in the temperature, great heats, or droughts, all of which so visibly affect plant life. During these periods of arrested

development the cellulose already deposited has time to solidify or harden to such an extent, that when growth is resumed only an imperfect union can be established between the layer previously deposited and the one which then commences to be formed. The phenomena revealed by Messrs. O'Neil and Butterworth accord in every detail with those of vegetable life in every other department. The concentric circles shown in the sections are precisely like the rings exhibited in the cross section of the stem or

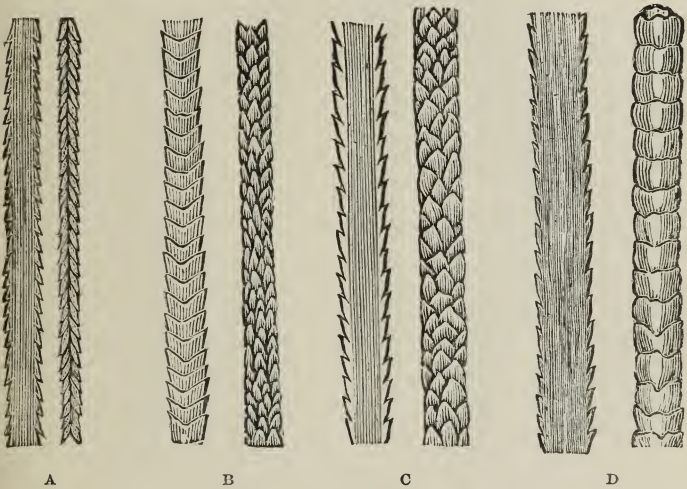


Fig. 18. Animal fibres and sections.

trunk of a tree, and which mark the season's growths ; the longitudinal fibres have their analogues in the fibres of the flax, hemp, jute, and other plants of a kindred nature, where greater strength is required to enable the plant to attain to maturity and to propagate itself than could easily otherwise be attained without the expenditure of additional material. This would have been a wasteful act, of which Nature, as the most perfect economist, is never guilty. Whether the reader agree with these conclusions or not,

it will readily be admitted that the phenomena are interesting, and a knowledge of them can hardly fail to be advantageous.

It will interest the student of spinning to see in what respects the fibre of cotton differs from fibres of animal origin. The accompanying illustrations (Figs. 18 and 19) of various classes of wools and hairs afford the means of making this comparison: A represents a fibre, and longi-



Fig. 19. Animal fibres and sections.

tudinal section of another, of merino wool; B similarly shows the Southdown wool, one of the finest and shortest of English wools; C and D Leicester and Lincoln wools, or the long wools of this country, one portion of which are also known as lustre wools, extensively used in the Bradford trade. A common, coarse wool is shown in F; whilst G represents goat's hair. H shows a fibre of mohair; I, cowhair; and J, human hair. The finest wools are from $\frac{1}{700}$ to $\frac{1}{900}$ inch in diameter, and contain from 2,600 to

2,900 serrations in the inch; medium fine wools are from $\frac{1}{500}$ to $\frac{1}{700}$ inch in diameter, and contain from 2,000 to 2,500 serrations per inch. Coarse wools include all below $\frac{1}{500}$ in diameter, and a corresponding diminution of the serrations.

The knowledge acquired during the progress of the art of cotton manufacturing has resulted in establishing certain general principles or truths relating to the art which cannot be disregarded when it is desired that the best possible results should be the outcome of the operation. These may be briefly summarized as follows:—

That the selected cotton should be as uniform in quality as possible—that is, in the length, strength, diameter, and convolutions of the fibre,—and should be uniform in softness and colour. When, from economical considerations, it is advisable to mix different varieties in order to lessen the cost, regard must still be had to this principle, in order to secure the most perfect combination of the fibres, the greatest product in yarn, the least in waste, and the thread of the yarn uniformly solid, round, even, and strong.

Cotton should be thoroughly “mixed,” even when only one class is used—that is, the contents of the different bales should be spread in thin alternate layers upon each other, in order to modify any accidental difference in the bales arising from any cause, such, for instance, as careless or wilfully false packing. When several varieties are used, this is absolutely necessary, in order to secure thorough incorporation, and a uniform condition in the blend.

The raw material must be thoroughly “opened,” and cleaned from impurities—that is, the matted fibres must be disentangled, freed from sand, dust, seed, leaf, unripe fibres, and any extraneous substance that may by accident or otherwise have been introduced.

The fibres must next be laid in parallel order, and so conducted through the successive stages of preparation until that of spinning is reached. This must be accom-

plished without the fibre being strained, doubled, broken, rolled, or otherwise injured. When cotton is strained, its convolute form is to a great extent destroyed, the power of the fibres to interlock with each other when being spun is greatly diminished, and the strength of the yarn correspondingly lowered.

The strength of a fibre of cotton is measured by the weight it will raise without breaking. The maximum possible strength of a yarn is the aggregate strength of the fibres which compose it, as shown in a section. This, however, can never be obtained in practice, it being a well-known fact that torsion does not increase, but greatly diminishes the strength of fibres to which it is applied. This fact teaches us that yarn should not be twisted more than is necessary to secure the proper cohesion of its fibres when under tension, if it be desired to obtain its maximum of strength.

These are the scientific principles of cotton-spinning, as demonstrated by all past experience, and the highest form of the art is that in which they are most perfectly embodied in practice. There are, however, few, if any, instances in which the best result attainable is ever directly sought. The economic question is always intruded, and the problem resolves itself into one of how to make the best article possible, consistent with securing a profitable sale for the product. This, it will be obvious, is a very different matter from the preceding one; and as it constantly confronts the practical spinner in the conduct of his establishment, it ought to be thoroughly comprehended, and its importance fully appreciated by the student of the art, and the working men employed in each branch of the trade.

CHAPTER III.

THE MILL.

Essentials of successful spinning.—Divisions of the trade.—Selection of locality; supply of operatives; proximity to markets for purchase of raw materials and disposal of productions.—Site of mill; sheltered position, humidity, soil, water.—Roads; advantages of proximity to residences of workpeople.—Materials decided by circumstances.—Systems of construction.—Illustration. Fire-proof mill; points of importance in structure.—Arrangement of interior.—Engines; transmission of power to machinery; gearing, belting, ropes, advantages and disadvantages.—Arrangement of machinery.—Steam and water power.—Boilers and their adjuncts.—Care against corrosion.—Incrustations; their variety, danger, and wastefulness; soda, sometimes a remedy; economical heating.

COMPETITION in the cotton trade is now so severe, both at home and abroad, that anyone newly adventuring therein cannot afford to neglect the slightest matter that may be conducive to success. If possible the beginner should start with a sufficiency of capital to secure a perfectly new establishment, well found in every respect, and have a balance left large enough to conduct its commercial operations with advantage. Without a level beginning, the chances of success are proportionately diminished. The locality must be well chosen, the site of the mill carefully selected, the mill well constructed, the machinery must be of the best for its particular purpose, the management must be skilful, economical, and thoroughly honest. The manager must be perfectly versed in the practical details of his business, and able to manage men as well as machines. The commercial division of the business must be conducted with skill, prudence, foresight, and a fair share of enterprise. Old methods of procedure must not be re-

tained from an excess of conservative sentiment when it is obvious that they have been superseded by improvements; and machinery must not be retained in work, though intrinsically in good condition, when mechanical invention has rendered it virtually obsolete. Anyone not willing to recognize and act upon these truisms had better not invest his means in the cotton trade. Technical, scientific and commercial knowledge, combined with steady industry and prudent enterprise, are required to ensure success.

The following pages will be devoted to an exposition of the means whereby, from the materials employed, the highest quality and the greatest quantity of production may be obtained at the smallest cost. This task will be rendered all the more easy by the fact that there is no antagonism in the methods: what conduces to one result being equally favourable to the other.

The mechanical treatment of cotton—the processes it undergoes in its transformation into yarn—take place in the mill. This, to most readers of the present essay, will be a familiar edifice, though all may not be acquainted with the essential qualities of a good or first-class mill, nor with the conditions by which it should be surrounded.

Cotton-spinning is divisible into three or four branches: the fine trade, chiefly located in Manchester and immediate neighbourhood, in which the finest cotton yarns are produced; the medium fine trade, of which Bolton is the great centre, and which is also found to some extent in Chorley and Preston; the medium trade, which constitutes the great bulk of the cotton industry, and is principally located in South-east Lancashire, and to a considerable extent in the weaving districts of East Lancashire; the coarse trade which has its seat mainly in Oldham, Rochdale, Todmorden, and the Rossendale Valley districts, and the waste trade spinning up the refuse material of the preceding branches, which is almost concentrated in Oldham.

Having decided which branch to follow, this will, to some extent, decide the selection of the locality; this in all cases ought to be a place in which an abundant supply of trained and experienced hands can be had. Consistently with this, it should be in near proximity to the principal markets for the purchase of raw materials, and the sale of the produce; the cost of carriage inward and outward, rather than distance merely, being the point on which a favourable decision should hinge. The first is necessary to success, as without it the production will be less than it ought to be, thereby being burdened with a heavier proportion of the fixed expenses of the establishment than is that which comes from competing mills which yield a high average; the quality of the article produced will be inferior, and will therefore sell for less money; the amount of waste will be excessive, and the depreciation of the working plant unduly rapid. The important character of these considerations, which relate mainly to the internal economy of the establishment, will be obvious without further remark. The second is connected chiefly with the commercial conduct of the business, and is important, on the ground that carriage charges for material or product should not be a tax upon the profits; but its chief value consists in affording facile access to the markets in order that the persons charged with the duty of buying and selling may always be on the spot to take advantage of momentary phases of weakness or strength that may pass over the market: the former offering advantages in buying, the latter in selling. If other circumstances than these decide the selection of locality, care should be taken to see that they fully compensate for the loss that will arise from the absence of these advantages. The satisfactory determination of these points is extremely important, because it can easily be demonstrated that it would be more profitable to plant a mill in a locality possessing skilled labour and in proximity to the markets, paying full prices for buildings and machinery, and providing a sufficiency of

working capital, than it would be to accept one of the same capacity as a free and untrammelled gift, but located in a place not possessing these advantages. At the end of a period of fifteen or twenty years the proprietor of the former would be able to retire with a fortune, whilst the owner of the second would be penniless, or only the possessor of a worn-out mill, which it would be folly to work in competition with such as the first. The truth of this statement has many times been amply demonstrated.

The locality having been decided upon, an appropriate site needs to be found. A few practical considerations, which should always be carefully attended to, will help to settle this point. Cotton, it is well known, spins and weaves best in a warm humid atmosphere. A valley protected from dry winds and open to moist ones will therefore afford eligible sites ; in other words, having particular application to the English manufacturing districts, it should be sheltered on the east and north, and open to the west and south. The subsoil should be of stiff impervious clay, which will afford a solid foundation for the mill, and in the vicinity retain the rain-fall, as it were, in a subterranean reservoir, evaporation from which in the driest seasons will moisten and soften the atmosphere of the locality—a great advantage at such times.

An abundant and never-failing supply of water is an essential requisite, otherwise space for an artificial reservoir will be required ; the latter will be best and most economically formed on a clay subsoil.

Good roads giving easy access for cartage purposes, and to and from the residences of the operatives, are important. The site should be within such a distance of the homes of the latter as would permit all employed to go to meals and return within the time legally provided for that purpose. Of course there will always be some exceptions, in which operatives will come from too great a distance to permit of this, and provision has then to be made for allowing food to be taken upon some part of the premises

not amenable to the visits of the factory inspector, or where the law would be liable to be violated, entailing responsibility upon the owner. This state of matters always entails some extra supervision, and consequently cost and risk. A short walk in the open air, such as is had by going home to food, is always invigorating and promotive of health amongst the operatives, and ought, in all cases where practicable, to be encouraged. It refreshes them and breaks the monotony of their labour, to which they afterwards return with renewed strength.

The fittest material for the edifice will be decided by the circumstances of the locality. If stone lies in close proximity and can be easily quarried, it constitutes an excellent, durable and cheap material. When stone is not conveniently near, and the site selected contains clay from which bricks can be made, these will generally be found the most economical and suitable article. Should it be necessary to provide a reservoir for water, any clay excavated for this purpose, and also that obtained from the foundation trenches, will be available for this use.

The systems of construction are various, and circumstances will best decide which shall be adopted. Mills have ordinarily been erected on the non-fire-proof system, but this of late years has become almost obsolete. Another method is the partial fire-proof plan, in which the portion most liable to destruction by fire—until recently considered that part of the mill in which the preparatory machinery is located—is constructed as far as possible without timber. Of late, however, in consequence of the acceleration of the speed in every department, and especially in the spinning-rooms, both for mule, throstle, and ring frames, the risk of fire has been rendered equally great in these departments. The experience of the past few years, which has afforded many examples of this fact, has established the public preference for the most modern plan, in which the whole structure is made as nearly fire-proof as possible.

As an illustration of this system of mill architecture, a

plan, longitudinal and cross sections (Figs. 20, 21, 22) are given. These were prepared from drawings kindly furnished by A. H. Stott and Sons, mill architects of Manchester and Oldham, and will adequately represent the method of construction such as now prevails throughout the spinning districts of South Lancashire.

To facilitate description, let it be assumed to be the plan of an actually existing mill. On this supposition the dimensions of the main portion of the structure are 295 ft. \times 125 ft. It has four flats and a cellar. The four flats are of sufficient capacity to contain 75,000 mule spindles with adequate preparatory machinery. The foundations are of coarse rubble on one foot of mortar concrete. Those on which the columns immediately rest are of flag-stones. The walls are composed externally of pressed brick, and internally of common brick. The window sashes are glazed in the lower part with rough plate, and in the upper part with clear glass. The floors are supported upon cast-iron columns, in which brackets or arms are cast. To these are secured rolled iron beams, the object being to get two arches in place of one. Each pillar bracket is connected with the next by an arch beam, to form a complete continuation between the pillars and in the direction of the brackets. The brick arches are 7 inches thick at the base, diminishing to $4\frac{1}{2}$ inches at the crown. They are turned between the beams. Timber joists $2\frac{1}{2}$ inches deep are laid across the beams, and the space between filled up with concrete. When this has become thoroughly dry, the floors are laid with $1\frac{1}{2}$ inch deal boards nailed to the joists. Boarding is, in many respects, preferable for all floors except cellars and blowing-room. The floor of the cellar should be composed of bricks laid on puddled clay, with passages formed of cement concrete or flag-stones. The roof is constructed in the same manner as the floors, but the concrete is laid level, and then covered with two coats of asphalt, each $\frac{1}{2}$ inch thick. These coats are turned up the wall 18 inches all round, and protected

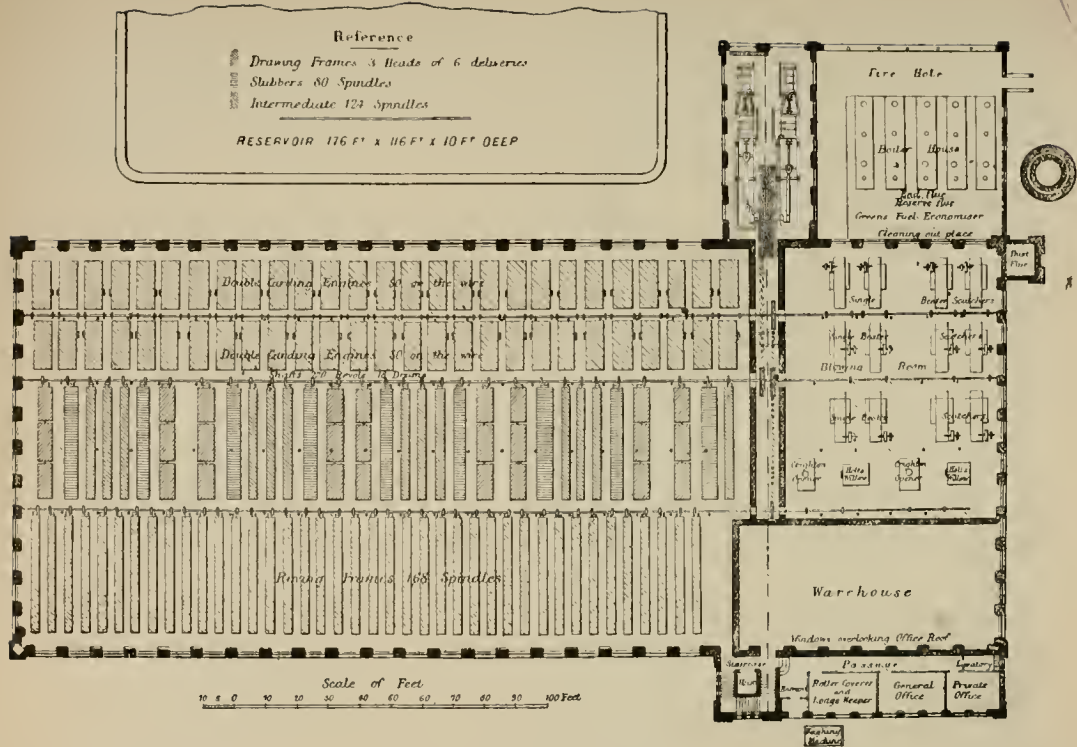


Fig. 20. Plan of Cotton Mill. Ground floor.

To face page 62.

from the weather by a dwarf brick wall built inside on the asphalt. Constructed thus, the roof forms a reservoir capable of containing 6-12 inches water. The object of this is to render it thoroughly fire-proof. A greater depth of water is sometimes preserved, and arrangements made for utilizing it at a moment's notice in the event of fire. When this is adopted, conduit pipes are laid to and around the interior of each room, and provided with the necessary taps. The stair-case is composed of stone treads with cast-iron risers.

The roof of the engine-house is fire-proof, and supported on large rolled iron girders; that of the boiler-house is of ordinary construction, containing ventilators. The chimney is planned for an altitude of 210 feet, with an external diameter of 17 feet, and an internal one of 8 feet, tapering to an external diameter of 9 feet 10 inches, and an internal one of 7 feet 6 inches at the top.

The points of chief importance in the construction of a cotton mill, and which require careful attention in providing, are a solid bed for foundations, sound bricks or durable stone, and good mortar. The walls should be thoroughly true, well set, and quite perpendicular, and of such strength as to reduce vibrations to a minimum. Windows should be large to secure abundant light. The floors should be so constructed that no cavities are left in them to afford lodgment for loose "fly," waste, and similarly dangerous matter, that is liable to spontaneous ignition, and may result in the burning of the structure. The inner surfaces of the walls ought to be smooth and even, in order to prevent "fly" collecting upon the inequalities, whence, by a sudden inrush of wind on the opening of a door or window it might be blown upon a gas jet, and a conflagration ensue. Every care should be adopted to secure immunity from the latter contingency, which means the absolute destruction of so much capital. In many cases a mistaken notion prevails that a proprietor is recouped by means of insurance against the danger, but this is not

the case. The insurance premium is a heavy tax upon the earnings of a mill, but though a wise provision, and one that ought never to be neglected, it does not diminish the disaster to the extent of a shilling. A proprietor who has his mill destroyed after the payment of the first premium, and receives the full value, has simply received engaged contributions from the profits of other mills to make good his loss. If this subject was thoroughly understood and its importance fully appreciated, it would lead to more precautions being taken to prevent fire, and to promptly extinguish it when it has broken out. This might easily be done at less cost than the amount of one annual premium, and the liability to destruction be reduced one-half in consequence, whereby a great reduction in the fire-tax ought to be obtained.

Returning to the description of the mill: the arrangement of the interior is as follows:—The ground-floor contains the blowing-room, carding-room, warehouse, offices, and entrance lodge. Over the carding-room are three spinning rooms of equal dimensions. Above the blowing-room and warehouse are situated the mixing-room for cotton, and store rooms for sundries. Partially over the mixing-room is the bale-room, provided with a door opening on the end of the mill, and fitted with a self-acting hoist. Level with the bale-room is the reeling-room, and over these is a twining or doubling-room. The boiler-house at the back of the mill contains five Lancashire boilers 30 feet long and 7 feet diameter, each having two circular flues 2 feet 9 inches diameter at the firing end, tapering to 2 feet 4 inches. Behind the fire are inserted six Galloway tubes. The boilers are fed with water from the hot well of the engine. Behind each boiler is fixed a fuel economizer of ten pipes width: in all 360 pipes. Passing through these, under the waste heat from the furnaces, the feed-water attains a temperature of 280° F. before reaching the boilers. The latter are usually worked at a pressure of 90 lbs.

The engines are of the tandem type, with low pressure cylinders in front and high pressure behind, on the same piston; the former are 40 inches diameter, the latter 21 inches. The stroke is 6 feet. The air-pump is situated under the slides of the piston-rod, and is worked by a bell-crank lever; it has a stroke of 3 feet. The condenser stands by the side of the air-pump. The ordinary vertical type of the latter is still the most popular amongst practical men. The fly-wheel is 30 feet diameter; its periphery is 5 feet 6 inches broad, and is grooved for the reception of twenty-three ropes. The grooves are V-shaped, and of such depth that the ropes do not touch the bottom. The ropes are of hemp or cotton, the latter proving most durable in wear; they are made in different ways. In the centre of and extending around its periphery are cast a set of cogs for barring the wheel round; these can also be used for moving it by a small bar-and-ratchet arrangement.

Power is transmitted directly from the engine to each compartment of the mill by means of the above-mentioned ropes, which are received by a grooved drum fitted upon shafts that extend throughout the length of the mill. In the carding-room the central shaft driven from the engine is turned by five ropes, and makes 220 revolutions a minute. Two other shafts, one on each side, run parallel with the central one, and are driven from it by ropes at the same speed. The shaft nearest the rear of the mill supplies the motive power to the carding engines; the middle shaft to the drawing frames, slubbing frames, and intermediates; whilst the one furthest from the engine drives the roving frames, the willows, and the openers. In the spinning rooms the shaft driven by the engine extends the length of the mill, and makes 220 revolutions a minute. In the top room a shaft is carried over the warehouse part, and drives the twining-jennies. The bale-room, which receives the raw cotton as it is hauled in from the mill yard by means of the automatic hoist, is provided

with openings in the floor, bound with cast-iron frames, having covers of the same material. Similar provision is made in the mixing-room for passing the raw material to the blowing-room. At the corner of this room nearest the chimney is a dust-flue for carrying away the dirt and sand, separated from the cotton by the willows, openers, and scutchers.

The system of transmitting power by means of ropes is of quite recent introduction, having been originated, we believe, in the north of Ireland amongst the flax mills, whence it was shortly introduced into Scotland, and thence quickly found its way into the cotton manufacturing districts. When it was comparatively little known the present writer, through the medium of the *Textile Manufacturer*, drew the attention of the trade to its great advantages. These were so obvious, that in public estimation it has now taken the lead of either the old system of gearing or the more modern one of belt driving.

In first cost it is fully 30 per cent. less than either gearing or belts; it is free from the great risk and danger attending the fracture of gearing, and is clean and noiseless in operation, adding much to the comfort of the workers, diminishing the cost of superintendence, and to a great extent obviating "break-downs," with their destructive results and disorganization of business. The ropes are always sufficient in number to allow of one or two being thrown off, if need be, for replacing when worn, or tightening when slack, which is done by cutting a portion out and splicing the ends together. A rope can be thrown off any meal time, and be got ready for replacing by the time the next stoppage occurs, the engine running and the mill working just as usual in the meantime.

The machinery is arranged with a view of rendering the processes consecutive, and to incurring the least possible cost for handling the cotton as it passes through. For a mill of the dimensions indicated, and designed for spinning what are known as Oldham counts, two willows and two

openers are required to serve twelve single beater scutchers. These provide laps for fifty-four double carding engines, 50 inches on the wire. Sufficient sliver is produced on these to supply nine drawing frames of three heads of six deliveries each, which in their turn serve nine slubbing frames of eighty spindles each, whilst the latter give full employment to twelve or thirteen intermediates of 124 spindles each, the production of these being taken by forty roving frames of 168 spindles each. In a mill spinning 32^s. warp yarn and weft to correspond, the above-named preparatory machinery suffices to supply the complement of spindles, about 70,000. Twining or doubling is a subsequent process.

In England steam is usually the motive power employed for driving a mill; on the continent and in America water-power obtained from falls and running streams is often used. The varying quantity and the uncertainty of the supply, however, renders this an unreliable source of power. Of recent years, therefore, auxiliary steam power has frequently been laid down where it was not desirable that the processes of manufacture should be interrupted.

There are many varieties of boilers, differing in construction and details according to the views of the respective makers, but into these the limits of space will not allow us to enter. The same objection applies to all discussion of what may be termed the adjuncts of boilers, such as furnaces, fuel economizers, injectors, water and steam gauges, &c. A few general remarks must suffice.

In furnishing a mill the boiler power should be sufficiently ample to leave a good margin beyond all demands, besides a spare boiler, to be used when the others are being cleaned, or are undergoing repairs. The best form of boiler is that which will generate steam the most quickly with the least consumption of fuel. It should be of good form, so as to possess an equal power at all parts of resisting pressure. It should be well and equally stayed. All valves, gauges, &c., should be simple, not liable to get out

of order, and be easily accessible for inspection and repair ; every necessary for their safe and proper working should be provided and be close at hand. The boiler-house should be rain-proof, and the boiler be carefully guarded against water in contact with its external surface, by which it might be corroded and weakened. Internal corrosion, the most frequent cause of boiler explosions, can be reduced to a minimum by the use of a good feed-water heater, in which the supply of water should be raised to a temperature of about 200 degrees before it is injected into the boiler. This heat expels the atmospheric air, the oxygen of which is the chief source of corrosion. The best plan of all would be to render boiler plates incorrodible by the application of a coating of magnetic oxide, which would increase the safety and durability of the boilers very greatly. Of late years great improvements have taken place in the construction of valves and gauges, and every boiler should be fitted with the best forms, incorrodible, and secure against being tampered with. Gauges should be cleared from sediment by frequent blowing out.

Incrustations in the boiler are a source of expense, trouble, and great danger. The nature of incrustations differs according to the nature and quantity of the minerals with which the water supplied to the boilers may be charged. This varies in different districts. An enormous waste of fuel results from the presence of scale or incrustation. A deposit of $\frac{1}{16}$ in. thick, will require the consumption of 15 per cent. more fuel, and $\frac{1}{4}$ in. 60 or 70 per cent., whilst scale of $\frac{1}{2}$ in. thickness would require 150 to 170 per cent. more than would be needed to obtain a given pressure of steam without them. According to experiments that have been made in the United States steam can be generated to maintain a pressure of 90 lbs. per square inch, with the water heated to about 320° F., which, with a well-constructed boiler having $\frac{1}{4}$ in. plates, will require a furnace heat of about 5° over this. When scale is present, however, the heat required is enormously increased, so that in the pre-

sence of scale $\frac{1}{2}$ in. thick, the furnace temperature would require to exceed 700° . This, of course, no boiler could be safely put to. From this it would be obvious that for economical and safe working, boilers ought to be kept carefully cleaned. The formation of scale is a great annoyance, and its removal a source of difficulty and severe labour, having usually to be chipped off by hammer and chisel. Deposits which do not cake and form scale are much more easily removed, and the chief objects of anti-incrustation articles is to secure that all deposits shall be laid in the form of friable dust which can be blown off. Necessarily the chemicals employed to effect this purpose must be varied in different districts according to the chemical constituents of the waters in use. An eminent firm in Manchester has found an efficient remedy in the addition of a little carbonate of soda or soda ash to the feed water, the water thus being preserved in an alkaline state. For over fifteen years this has enabled them to do without chipping any boiler on their premises.

The construction of the boiler seat should be such as to utilize the heat of the furnace to the fullest possible extent, and to prevent all loss by reducing radiation to a minimum. To secure these ends care must be directed to bringing the heat from the furnace into contact with the boiler surface wherever practicable, and that which is unused after passage through the flues ought to be utilized for heating the feed water before it escapes up the chimney. All the materials employed for the lining of the boiler seat ought to be non-conductors of heat.

A regard for economy, efficiency, and durability should govern every step decided upon in the arrangement and construction of a mill from the choice of site, through the erection, and down to the smallest detail of the mechanism.

The construction of the furnace, the plan of the bars, and the use of mechanical stokers in order to secure the perfect combustion of fuel, are matters demanding careful investigation and consideration. These are, to some ex-

tent, dependent upon the kind of boiler employed, but of all there are several varieties to select from, and approximate efficiency can be easily attained.

Engines are obtainable now in almost any conceivable type to suit requirement, but for turning a cotton mill the old vertical form, or beam engine, or the more modern horizontal are generally selected as the most reliable, economical and durable. In both these makes a high degree of excellence has been obtained, and the purchaser will have no difficulty in suiting his requirements.

There are three principal means of transmitting motive power, by gearing, belting, and ropes. The first is the one which has been in vogue for a long time, and it has until quite recently maintained the lead in public estimation, but more from the absence of competitors than from its intrinsic merits. It is a crude system, and mechanical engineers have never been able to eliminate its numerous defects. It is costly in the first instance, expensive to maintain, and liable to very destructive breakages. Its minor evils are that it is dirty, noisy, and incommodious for examination or repair. Nearly all these evils are obviated when the plan of driving by belting is adopted. The first cost, however, is not much reduced, as, owing to the necessity of employing the best quality of material in order to secure satisfactory results, and the high price of leather, the expense closely approximates to that of gearing. Sometimes cotton belting is substituted with advantage. Rope-driving is of more recent introduction. This system possesses advantages over both the preceding: in first cost, which is much less, in freedom from liability to break down, in facility for effecting repairs, and probably, though on this point the opportunities of satisfactory tests have hardly yet been afforded owing to its novelty, in durability.

CHAPTER IV.

MANIPULATION OF THE MATERIAL.

Cotton spinning, definition.—Processes defined : ginning ; packing ; mixing ; willowing ; opening ; scutching ; carding ; combing ; drawing ; slubbing ; intermediate ; roving ; spinning ; doubling.—Cotton testing ; test-book ; mixing-book.—Hand-labour superseded by machine-labour ; the operative a superintendent.—Cotton spinning : preparatory and constructive processes.—Mixing ; preliminary examination and classification of the cotton ; large mixings better than small ones ; importance of securing equal lengths of staples ; process of mixing ; testing ; mode of using ; prescribing mixings ; mixing in the lap.—Willowing or opening ; general principles ; the Oldham willow, common and improved ; the Crighton opener and its operation ; the porcupine ; the pneumatic feeding opener ; an American opener.—The purposes of opening.—Injuries arising from adulteration.—Injuries from excessive willowing.—Imperfections of the willow ; better principles of the Crighton and the pneumatic feed openers.—Scutching, its purpose ; importance of correct feeding in the scutching machine ; the scutching machine, hand-fed ; trustworthy attendants ; automatic weighing.—Influence of temperature and atmospheric states on the weight of laps.—Lap-feeding ; the piano feed, its action.—The finisher lap machine, its function ; description.—Well made laps ; causes of unequal laps.—A new automatic feed suggested.—Clayton's lap roller.—Remarks : qualities of this class of machines ; speeds ; construction ; cleansing ; oiling.

THE practical details of the art and the machinery employed in it now demand consideration.

The manipulation or mechanical treatment of cotton in all its processes up to the production of a cloth, after ginning and baling in the country of growth, takes place in the cotton mill. An enumeration and brief definition of these processes at this point will obviate much repetition.

“Cotton spinning” implies in the aggregate every operation involved in transforming raw cotton into yarn—

that is, into a single twisted strand or thread composed of cotton fibre. "Spinning" has also a more restricted signification, being used to denote the concluding process of the series.

The writer, in another place,¹ has defined the processes of manipulation, mechanical and otherwise, that cotton undergoes in being converted into yarn from the state in which it is gathered from the plant, as follows:—

1st. "*Ginning*."—This is usually performed in the vicinity of the cotton plantation, the object being to remove the fibre from the seed of the plant, and partially to cleanse it from foreign matters.

2nd. "*Packing*" or "*Baling*."—After ginning, the lint is in a loose state, and unfit for convenient transport to distant markets; hence it is necessary to compress it into less space, which is ordinarily performed by means of hydraulic presses. The package leaves the press in the well-known form, technically called a bale, in which state it passes through the markets to the hands of the spinners.

3rd. "*Mixing*" is the blending of different varieties of raw cotton, in order to secure economical production, uniform quality and colour, and an even thread in any desired degree. Even when using only one class or variety of cotton, mixing is in a measure imperatively necessary, in order to neutralize the irregularities of growth and imperfect classification found more or less in all grades of cotton. It is the first operation in a cotton mill.

4th. "*Willowing*."—This is a process of opening and cleaning cotton which, except in the Oldham district, is not much in vogue in modern mills, and is retained chiefly for opening and cleansing low cottons, waste, &c.

5th. "*Opening*."—In consequence of the heavy pressure to which cotton is subjected in packing, the fibres become strongly matted together; the opening process is to

¹ Art. "Cotton Manufactures," Spon's "Encyclopædia of the Industrial Arts, Manufactures, and Commercial Products."

loosen them, and to remove the heavier portion of the foreign substances that may be intermixed. It is the present equivalent of willowing.

6th. "*Scutching*" has a two-fold object, namely, the further extraction of impurities, and the formation of a "lap," which is a web or sheet of cotton formed in the machine, and wound upon a small roller. In this web the fibres lie in all directions.

7th. "*Carding*."—The foregoing operations have dealt with cotton in the bulk. In carding, the process of opening is continued, but the material is treated in its individual fibres, which are taken from the lap, further cleansed, and laid in a position approximately parallel to each other, forming a thin film, which is afterwards condensed into a sliver—a round, soft, and untwisted strand of cotton. In this process all short, broken, and immature fibre is, as far as possible, removed.

8th. "*Combing*" is used for the production of fine yarns, or those of high quality. Its object is to obtain uniformity in the length of the fibres undergoing preparation. To accomplish this, all those shorter than the required standard are combed away and rejected. It is not ordinarily used for any but the above purposes.

9th. "*Drawing*."—In this operation, several slivers—the product of the carding process—are combined, and attenuated to the dimensions of one of the component parts. The objects are to render the new sliver more uniform in thickness, and to place the fibres more perfectly in parallel order.

10th. "*Slubbing*" is a process by which a further combination of slivers is effected, and the objects of drawing are more perfectly accomplished. The drawing or attenuation of the strand is now carried so far that it becomes necessary to twist it slightly, in order to preserve its cohesion and rounded form.

11th. "*Intermediate*," or "*Second Slubbing*," is in all respects a repetition of the above, necessary in cases where

the most even and clean yarn is required. It is not ordinarily used in the production of low numbers.

12th. "*Roving*."—This is a continuation of the preceding, its principal object being to attenuate the sliver still further. At this point, also, the latter receives additional twist, to enable it to bear the slight strain necessary to draw it from the spool or bobbin without the formation of uneven places.

13th. "*Spinning*."—The concluding process of the series. The sliver is here attenuated to the required fineness, and is given the twist by which the thread is completely formed.

14th. "*Doubling*," sometimes a separate business, but more often an adjunct to the preceding, is a method of combining two or more threads to form a single cord, and is adopted in the production of many varieties of yarn which are used for widely different purposes.

The processes thus briefly defined constitute the operations of cotton spinning, and carry us as far in the manufacture of the fibre as it is designed shall be included in this treatise. It will be the object of the writer to describe the best ways and means now in vogue for attaining the end sought by each process, to point out defects where such may be obvious, and, if possible, to suggest improvements.

COTTON TESTING.—It is a customary and a wise proceeding to test each purchase of cotton to find the average loss of weight upon the same classes of the material, or upon the varieties that compose the mixing in use. A small quantity—say 5 lbs.—is taken from each bale, and passed in succession through the scutching machinery and the card, beyond which the test is not carried, as the loss that occurs after these passages is small, and can be easily estimated. The parcel is carefully weighed after coming out of each machine, and the particulars entered into a book kept for the purpose, called the test or loss-book, which thus becomes a valuable book of reference. The 5 lbs. of

cotton, on its passage through the opener or willow, probably loses 3 ozs., reducing the weight of what remains to 4 lbs. 13 ozs. Its next passage is through the scutcher, where it loses 2 ozs. more, the balance being 4 lbs. 11 ozs. The lap machine is the next passage to which it is submitted, and in this it most likely drops 1 oz. more; balance, 4 lbs. 10 ozs. Supposing there to be a finisher lap machine after the last-named, the loss on its passage through this will again be 1 oz. more, reducing the bulk to 4 lbs. 9 ozs., or thus far a loss of 7 ozs. = $8\frac{3}{4}$ per cent.

A second useful book in the cotton room is the mixing-book, in which are entered the dates of every cotton purchase, the quantity, marks, and numbers of the bales, and the gross, tare, and net weight of each bale at the time of receipt. If the cotton is suspected of being damp, each bale ought to be weighed again just before being used, and any difference recorded, for which either claims may be made, or the marks avoided in future purchases. The price per lb. of each lot should also be attached, as this is required to ascertain the cost of the mixing. Similar entries must also be made for any waste that may be introduced. In laying down the mixing, the quantity of each sort must be carefully noted, the prices attached, and the calculation extended, the totals added, and the sum divided by the number of pounds the mixing contains, the result being the average cost of the mixing put down. The test sample of the mixing before spoken of will show the percentage of loss upon it, after which the cost is easily calculable.

In the processes of manufacture the human hand, from which the word is derived, and which formerly performed nearly all the labour, has been almost entirely superseded by machinery. Very little is now left for the operative to perform, his or her task being reduced to one of scarcely more than continuous supervision. From the mixing of the cotton to the doffing of the yarn all the labour, strictly speaking, is accomplished by mechanical appliances. It

is important, however, that each machine should receive the most careful attention from those in charge of it, otherwise defects will occur, and faulty work be the result.

The processes of cotton spinning are naturally divisible into two portions : 1st. the preparatory ; 2nd. the constructive. The first chiefly consists of the cleansing processes by which the raw material is freed as far as possible from sand, dust, seed, and leaf ; and short, immature, and undeveloped fibre. These include willowing or opening, scutching, carding, and sometimes combing. In the second division is found carding, combing (where used), drawing, slubbing, roving, and spinning. Mixing is the first process, and does not, strictly speaking, come into either division. It, however, is the first that requires attention.

MIXING.—The class, quality, and numbers of the yarn it is intended to make having been decided upon, and purchases of suitable material made, the first step to be taken is to make a careful examination of all the stock of cotton proposed to be used for the purpose in view, in order to be assured that the proper quality has been received, and to guard against mistakes that may have occurred in delivery, errors of classification, false packing, and the differences of quality that is usually found to arise from the contents of the bales having been gathered at different periods of growth. It is usually performed by drawing samples from two or three parts of each bale, comparing these with others, and classifying or grouping them into lots having similar characteristics. Cotton gathered prematurely differs from that which is properly ripe in having fewer convolutions or “twists” in the fibre, and also in being softer and weaker. That which has been left too long on the plant, which is, in fact, over-ripe, is shrivelled by the excessive evaporation of the natural moisture of the fibre, and is thereby rendered hard and harsh, and combines badly with the softer and more pliable fibres of properly ripe cotton. It needs a considerable power of discrimination, which can only be acquired by experience, to discover these differences. The person

entrusted with the duty of classification ought to possess keenness of sight and great sensitiveness of touch, which he should carefully cultivate and develop to the highest state of perfection attainable in his case. It is well to make a mental note of the sensations experienced, and to associate them with the quality of the result obtained in the yarn. This examination and classification of cotton is too often carelessly, perfunctorily, or inefficiently performed, and an unsatisfactory product is the result. It is probable that if better attention was paid to grading the qualities more perfectly, it would not be found, as now, that in the best results spinners are only able to utilize about 25 per cent. of the strength of the fibres entering into the composition of their yarns.

In order to secure uniformity of quality in the product of a mill, it is best to lay down a mixing of cotton as large as means and convenience will permit. One that will last a month or six months is better than a small one that will last only a week, as every mixing causes some slight difference in quality or colour. Where the yarn is sold, these variations tend to excite suspicion regarding the good faith of the producer to his customer, and require on the part of the latter a constant watchfulness in order to prevent the changes proceeding to such an extent as to render the purchase unfit for its intended purpose. This suspicion will place any spinning at a disadvantage in the market, and tend to reduce the profit of a mill. Good management requires therefore that it should be avoided as far as possible. This can only be done in the manner indicated above.

Where different kinds of cotton are mixed together, the greatest care should be exercised in the selection of the staples, so that they may all be of one length, or as nearly so as possible. If short and long staples are put together, the result will be excessive waste and poor yarn; for rollers cannot be set to work two lengths of staple at one time with advantage. If they are set for the long staple,

the short will fall out and become waste ; if set for the short, the long will be broken and also fall out ; and weak and irregular yarn will be made. To combine the highest quality in the product, with the greatest economy of production, requires that long, short, or medium lengths of staples should each be worked by themselves. When waste is mixed with the cotton, which is practised in spinning low numbers, or making inferior qualities, it should be selected in this respect as like the cottons it has to be worked with as possible.

In laying down or mixing, the cotton should be taken from the bales and shaken loose upon the floor, covering an area suitable to the intended size of the mixing. When a layer of the first description of cotton has been put down in this manner, another from the second kind should be laid upon it, if the quantities of the sorts are equal, taking care that they are of the same thickness ; after this the third sort should be spread upon the top of the second, and so on until a layer of each lot has been laid, when the same course should be repeated until all the cotton has been laid down that it is intended should be included in the mixing. Sometimes, where only one or two varieties of cotton are in use, it is taken straight from the bale and passed through the willow without any preliminary mixing ; but, from what has been already stated regarding the nature of the fibre and the varying conditions attendant upon its growth, this will be seen to be exceedingly unadvisable.

Mixing is now occasionally performed by a machine in the Oldham district, and with satisfactory results.

The magnitude and quality of the mixing having been satisfactorily settled, the bales are taken from the classified stock in proper quantities, the coverings removed, and the cotton passed through the apertures in the floor to the men in the room below, where it is spread over an area proportionate to the size of the intended mixing. Sometimes a space is railed off from the remainder of the room, and

divided into compartments, each of which is capable of holding one mixing. The doors of those compartments containing mixings not being used, are kept locked. By this means they are prevented from being improperly used. Each bale will form a layer, and the different qualities included in the mixing will be superimposed in a regular order, so as to secure the most perfect blending of the mass in succeeding stages.

When the mixing is completed, it is generally tested by taking a vertical section of the blend sufficiently large to put through the different machines, in order to get the result in yarn, which is carefully examined and compared with that which is then being made; or, better still, with a standard sample of the class and quality it is desired to maintain. The latter is the best plan, as in the former it is possible to get far away from the desired quality by the accumulation of small differences, imperceptible in themselves, but which are capable of changing the character of the yarn when repeated a number of times. When thus tested by this standard, should the new yarn be found deficient in strength, cleanliness, or colour, a sufficient quantity of the cotton possessing the requisite qualities to bring it right is added to the mixing. In many establishments, especially where high class qualities of yarn are made, and it is imperative that its reputation should not be lowered, a second, and even a third, testing will take place before the result may be accepted as perfectly satisfactory. Skill, experience, and care, however, often avail to produce the required result, even without any preliminary test; but this is where few changes are made in either the standard of cotton purchased or the counts of yarn spun. Economical considerations, however, in these days of keen competition and low profits, often render it necessary to change the component parts or relative quantities of the mixing; and, in these cases, the application of the test ought not to be neglected. Where low qualities of yarn are spun, and waste is freely used, tests are seldom

considered necessary ; though, if the desire exists, or economical advantages would result from the production of a yarn uniform in quality, the plan of testing ought to be adopted.

The mixing having been found right in all the points essential to quality, it is ready for use. It will be obvious that were the supply required to feed the opener taken from the top of the blend, all the purpose of the mixing process would be defeated. To avoid this, the required quantity is carefully and evenly drawn down from the sides of the pile by a short-pronged rake, which secures a further intermixture of the mass.

The component parts of the mixing will necessarily differ according to the quality of yarn sought to be produced. Experience is chiefly relied upon for the result ; and most spinners of average skill are able to prescribe mixings with great accuracy that shall answer the problem before them. Still there is nothing like uniformity amongst them in this respect, many affecting to keep the particulars secret. The details given in a previous chapter show, in a general manner, the adaptability of certain cottons for spinning different numbers of yarn, and their suitability for admixture with each other.

Some spinners prefer to mix their cottons in the lap, especially when several varieties are used, and in equal quantities, or other proportions, such as will easily combine in the lap machine. In this plan it is usual to mix each kind alone, as already described, and laps are made from each mixing. Thus one lap each from three different kinds of cotton may be placed in a single scutcher, and by it united into one ; or two and one ; two and two, or any other desired proportions.

WILLOWING OR OPENING.—This is the first of the preparatory processes. The name “willowing” is derived from the treatment of cotton in the early days of manufacturing, when, in order to cleanse the cotton, it was spread upon an oblong frame, having a fine net of wire or other material

upon the bottom, on which the cotton was spread, when the mass was beaten loose and the dust driven out through the netting, by means of wands composed of twigs of willow or osier: hence the name. The latter was retained to describe the process when the means employed had altogether changed, and it has also been transferred to a particular machine now chiefly employed in the Oldham district. Willowing, therefore, implies at the present time the opening and cleansing of the raw material by mechanical appliances or otherwise. Of course the latter hardly exists, except in semi-civilized countries, where the primitive system of manufacturing still survives.

In England and other countries to which the English system of manufacturing has extended, willowing and opening is performed by several different machines, the principle of which, however, is in all cases the same. These differ only slightly in their arrangements, as all contain a cylinder denominated the beater, and which is arranged either horizontally or vertically, and either parallel with or diagonally to the direction of the passage of the raw material.

A brief explanation of these will best explain their construction, mode of operation, and their respective merits as openers and cleaners.

The common or Oldham willow is shown in the following Figs. 23 and 24, in section and plan. It consists of a cylinder, *c*, about forty inches diameter, and forty inches wide across the face. This, mounted on a shaft furnished with driving pulleys, rests in bearings in the framework. Fitted on, and extending across its periphery, are several rows of strong teeth or blunt spikes. A semi-circular casing, internally furnished with rows of spikes similar to the above, covers the upper part of this cylinder. The lower portion is enclosed with a wire grid, constructed in two parts, and hinged together. The back portion of this grid is fixed to the frame, whilst the front or movable part is hinged to the fixed part and is balanced by weights

suspended by cords or straps which pass over pulleys at each side, and which are attached to the end of the grid. It is thus free to move up and down in an opening in the front of the machine. An exhaust fan, *f*, is placed behind the fixed part of the grid.

The operation is as follows:—The grid is let down, and a quantity of cotton is placed upon it. It is then raised.

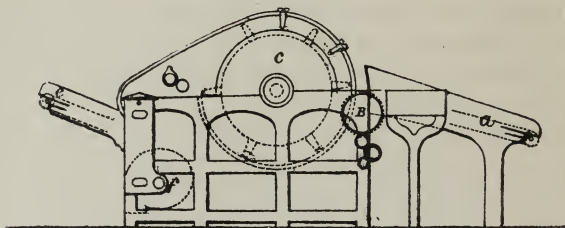


Fig. 23. Oldham Willow; side elevation.

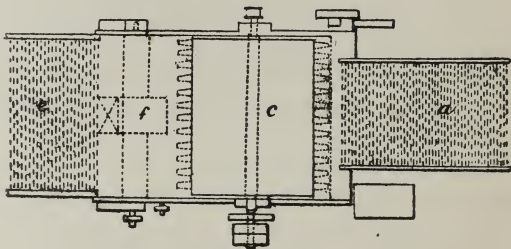


Fig. 24. Oldham Willow; plan.

and the cotton is thus brought into contact with the spikes of the revolving cylinder, which dash it against the fixed spikes on the internal face of the casing, loosening its matted fibres, and freeing it from sand, dust, and foreign matters which fall through the grid into the cavity below, or are drawn away by the operation of the exhaust fan and discharged through a tube into the air. After the cotton has been subjected to this operation for a few

seconds, the grid is let down, and the cotton discharged; the process is then repeated with fresh material. This is the simplest form of the willow as it exists in use in these districts.

The willow, however, of late years has undergone great improvements. It is sometimes made with an automatic motion to let down the grid when the cotton has been in the machine for the proper length of time, and which can be varied according to requirement. At other times it is made continuous, as shown in the illustrations (Figs. 23, 24), by placing a feed cloth, *a*, in front, and a lattice creeper, *e*, at the back, to carry away the cleansed cotton, which is then ready for delivery to the scutcher.

A second and favourite machine in the trade is the well-known Crighton Opener. This is a modification of the cone willow. The accompanying illustrations (Figs. 25 and 26) show the structure in section and plan. As will be seen, in the interior of the framework there is fitted a conical grid, with its apex or small end downwards, and resting on a cross rail at a short distance from the bottom. On the top of the frame is fitted a tripod, which forms a bearing for a vertical shaft carrying driving pulleys, and descending through the centre of the grid to a footstep in the cross rail. Mounted on this shaft are a number of discs, *b*, the smallest at the bottom, and increasing in size towards the top. Fixed on these are a series of steel blades, whose function is the same as that of the spikes on the cylinder and casing of the willow, to beat the cotton against the vertical grid. At the top of the grid is an orifice conducting to the dust cages. The space, *c*, between the casing and the grid forms a cavity for the reception of any foreign matter contained in the cotton. The machine is fed by means of the tube, *a*, which may be introduced on any side away from the attachment. The latter includes the dust cages, four, *f*, lattice creeper, *d*, and below the dust cages a pair of small delivery rollers, and an exhaust fan. The cages are hollow cylindrical wire frames, with

the wires set sufficiently close to prevent the entrance of the fibres of cotton, but wide enough to permit the dust to be drawn away by the current. Only the portion of the

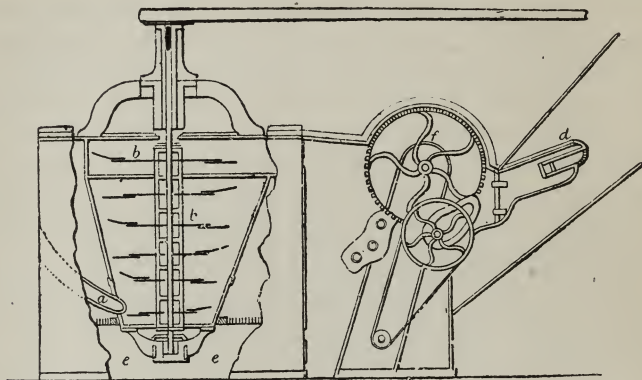


Fig. 25. Crighton Opener; elevation.

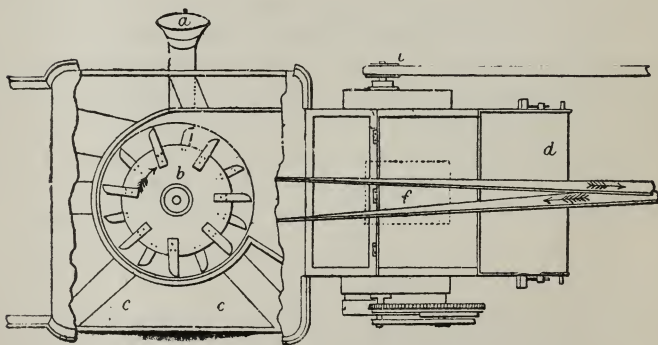


Fig. 26. Crighton Opener; plan.

cage opposite the orifice is left open, the remainder being closed by an internal casing which follows the contour of the cylinder.

The details of the process in this case are as follow :—

The cotton is fed into the tube, *a*, emerging therefrom into the lower portion of the conical grid, where it comes into contact with the beaters, *b*, which strike it against the bars of the conical grid. This action loosens the mass of fibre, and drives any sand, dust, or seed, and foreign substances left by the gin, if not too large, through the grid into the dust cavity, *c*, and thence to the bottom, *e*. The cotton remains subject to the action of the beaters, until it is opened sufficiently to admit of its being drawn upwards and carried away by the suction of the fan, *f*, through the orifice. Following the direction of the arrow towards the dust cage, it is taken on by the rollers, and passed to the lattice creeper, *d*, which discharges it upon the floor or into a receptacle provided.

The porcupine is another opener, whose chief difference from the willow, as described above, lies in the possession of two cylinders for opening purposes laid parallel to each other, the first of which has twelve rows of teeth, and the second four. It is fed and discharged by lattice creepers, and exhausted by the usual appliances.

Another opener combines therewith a scutcher and lap machine. The inventors largely avail themselves of the pneumatic principle seen in each of the preceding ones, and use a current of air to bring the cotton along tubes from any moderate distance. In the annexed illustration, Fig. 27, the feeding is represented as taking place in the room above the machine. An endless lattice, *A*, on which the cotton is evenly laid, delivers it to two pairs of rollers, *B*; the second pair of which revolves more quickly than the first. These convey it to the tube where it comes within the influence of the air current. During its passage through this tube, sand, dust, dirt, small stones, and all heavy or dangerous substances accidentally present with the cotton, are dropped upon the bottom of the tube. In order to secure the abstraction of these, the inventors devised and patented a grated trunk. Immediately between the feed table and the opener, several

lengths of these grated tubes, *c*, are inserted. Seen in sections they are shaped thus \square . Inside these, at short

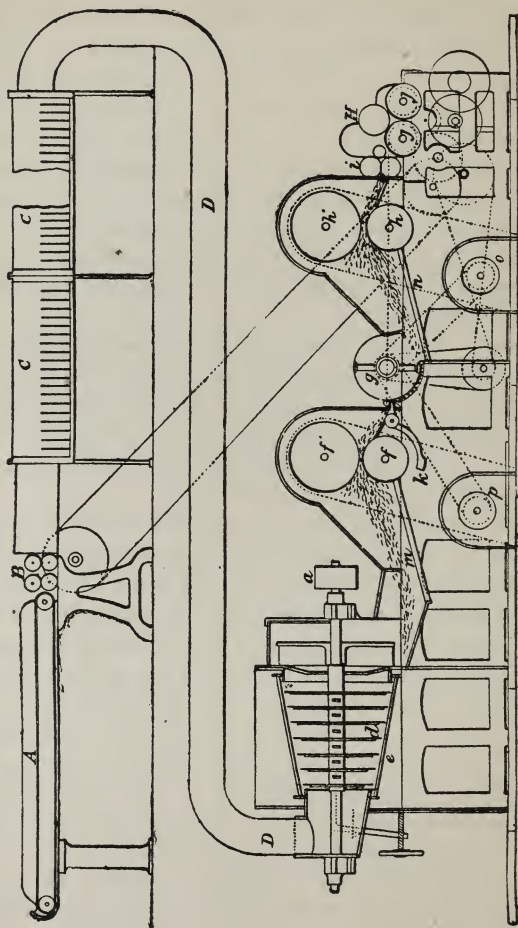


Fig. 27. Lord's Opener, with Pneumatic Tube.

distances apart, plates of sheet iron are placed athwart and slightly inclined against the direction of the air cur-

rent, and reaching about half way to the crown of the tube. The spaces between these plates form cells for the reception of extraneous matter, which, dropping out of the cotton, is retained in them. It is removed daily through the bottom of the tube, which is hinged for the purpose, and opens downwards. These cells prove very efficient dirt extractors, as is shown by the quantity of dust that is taken out of those in the front, and its gradual diminution towards the last, and by the small amount of foreign matter afterwards thrown off in the opener and scutcher.

The opener consists of a horizontal shaft, *a*, carrying a series of accurately balanced arms, *d*, arranged radially on the shaft at several inches apart. These arms are of cast-iron with steel blades bolted firmly to their extremities. The length of these arms is at the small end nearest the tube about eighteen inches. It increases gradually as the opposite end of the shaft is approached, terminating with a length of 28 inches. When revolving, the arms describe the figure of a cone. A conical grid, *e*, surrounds the beaters, which is constructed by the junction of two rings of unequal diameter connected by means of straight steel bars. This grid can be moved endwise upon the shaft by means of the wheel beneath the tube at the left extremity of the figure. The bars are fixed at the delivery end, but are capable of adjustment at the feed end in order to increase or diminish the distance from the beater, according to the length of staple or quality of cotton to be treated. On another shaft, at the delivery end of the beater, is a powerful disc fan, whose specific functions are to draw the cotton from the extremity of the feed-pipe, through the beater, to the dust-cages *f f'*; after passage through which the cotton is received by two small rollers that deliver it to the beater, *g*, of the scutcher, where it undergoes further opening and cleansing by a process resembling that received in the willow. It is then formed into a sheet upon the cages, *h h'*, compressed between

the rollers, *i*, and coiled into a lap in the lap-forming attachment, *H*.

There are several other makes of cotton openers, but almost all of them may be referred to the above in principle, and differing only in some minor detail. In one which stands in some favour in the United States, the inventor, an Englishman long settled there, has endeavoured to accomplish by mechanical means the exact results achieved by the primitive method of whipping the cotton with willow wands.

The question now arises which is the best of these methods of cleansing and opening the raw material? It will be well for a moment to revert to the requirements of the case. Cotton, as has already been made clear, besides being matted together owing to its severe compression for transit purposes, contains impurities of several kinds, such as sand, dust, broken leaf, seed shells, and short and immature fibre. It must not be omitted to recall the convolute form of the fibre, nor to remark that there is a soluble gum, which has received the name of cotton-wax, coating the fibre; the latter is present to the extent of from one-third to one-half per cent. The purposes of this process are to disentangle and separate the fibres from each other, or to render them so loose as to readily take up any new position in relation to each other that may be required in subsequent operations; and to remove, without injury to the fibre, as much as possible of the earthy impurities present, and also those of vegetable origin. The former being of much greater specific gravity, when permitted, easily fall away from the cotton; but the latter, being more nearly like the fibre, are separated with difficulty, and only a small quantity can be taken out in the opening process.

The accidental, or, as may be feared, too often fraudulent, adulteration of cotton by means of sand has become one of the most serious evils in connection with the trade. The presence of sharp, angular particles of flint and other

matters of which sand is composed, entails not only the loss of so much weight to the buyer, but it is the cause of serious injury to the staple.* It will be obvious that the compression to which cotton is subject in the baling process must, when sand is present, break and lacerate the fibre by forcing the particles into or through them, thus injuring the quality to an extent that has rarely been suspected. Particles also are forced into the substance of the fibre, or caused to adhere to the cotton-wax in such a manner that the opening machine cannot clear it out, the effect being that it is carried along through subsequent stages, to the great detriment of the rollers of the drawing, slubbing, intermediate and roving frames, which have their polished surfaces scratched and roughened, and the leather coverings of the front ones cut and damaged by its presence. These defects increase the quantity of waste and deteriorate the quality of the product. These facts ought to be strongly pressed upon the attention of cotton-growers and those who have the handling of the raw material before it reaches the spinner. The removal of sand proves sometimes so difficult that it has been found to have passed through all the preliminary stages and been discovered embodied in the yarn.

When the convolute form of the fibre is considered, and its preservation acknowledged to be essential to the production of the best quality of yarn, it will be obvious that all treatment in the opening process beyond that necessary for the disentanglement of the fibrous mass and the separation of the earthy particles must be excessive and injurious to its peculiar structure. It ought, therefore, wherever practicable, to be carefully avoided.

The willow, even in its best form, is not quite adapted to secure this end. It contains no provision for withdrawing the material at the exact moment when the opening and cleansing has been completed. The result must depend upon the skill, care, and judgment of the attendant, and as these are variable factors, liable to still greater

variation in their exercise, the most perfect work cannot be guaranteed. No arbitrary rule will meet the exigencies of the case, and the best judgment will, from necessity, often be at fault. The material will be either deficiently or excessively treated in nearly all cases ; the correct mean being seldom attainable. In the former it will come out partially matted or clogged ; in the latter stringy, and with its convolute form injured.

The only way by which these evils can be perfectly obviated is to remove the process from dependence upon the skill, too often absent ; the care, too often remittent instead of continuous ; and the judgment, generally fallible, of the attendant. This can only be done by making the process automatic. The feeding should be uniform and regular, and no stuffing be allowed. Of the openers now in the market, perhaps the most perfectly automatic, and one which meets these requirements most fully is that previously described (Figs. 25 and 26), which has met with such extensive approval in the trade, and in which the beater is arranged vertically. In this machine the cotton is fed to the bottom of the beater, rising higher and higher as it gets disentangled and becomes loose, until at the moment when the work is completed, it passes away from the range of its action on the current of air developed by the fan, which places it upon the periphery of the cage, whence it is received and delivered by a pair of rollers to the lattice creeper, and thence discharged. There is another merit in the vertical arrangement of the beater of the opener, which is this : its strokes being delivered in a horizontal direction are efficient in clearing the cotton from foreign substances, as in no case does this matter return into the cotton, as occurs when the beater is arranged horizontally, and delivers its stroke vertically. In the latter case, it may return several times before it is cast beyond the range of the beater blades. This, it is obvious, is a disadvantage. The provision of a pneumatic feeding tube, as seen in one instance, is an important improvement, for

two reasons. The first is, that without any violence the grosser and heavier impurities are removed without injury to the staple, and deposited in the dirt cells of the tube, which preliminary treatment obviates the necessity of subjecting it very long to the action of the beater. The second reason is, that when, as is far too often the case, especially with American cotton, the material is damp and correspondingly heavy, subjection to the beater has a tendency to injure the staple, as from its increased weight and the force with which it is driven the convolute form of the fibre will be often impaired, if not destroyed. By the introduction of the pneumatic tube, and the passage of the cotton through it, all excess of moisture is removed by the absorbent power of the air. The material is thus sent forward to the beater partially cleansed, dried, and in the best state for the operation to which it has to be submitted, which is thus performed in less time and with a minimum of injury.

SCUTCHING.—The next process, which is scutching, has a twofold purpose. The first being to further cleanse and open the cotton; the second to make a lap. The latter is a continuous sheet of cotton about forty inches wide, which is formed into a roll of convenient length to suit the machinery in the next process. In the lap the fibres lie in all directions across each other, no attempt having been made to arrange them in parallel order. If the raw material has not in the previous stage passed through an opener with a lap-forming attachment, it arrives at the scutcher in bulk, and but imperfectly cleansed and opened.

Nearly all openers, however, are now fitted with lap-forming attachments, because these facilitate the even feeding of the scutcher or finisher lap machine, and, in addition, dispense with labour. For some of the lower counts the laps thus formed are taken straight to the cards, but this is not often the case, nor is it desirable unless in rough coarse yarns.

The object sought as the outcome of the processes of

this division, is to transform the fibres of the raw material into a continuous cylindrical thread ; throughout its length as equal as possible in its diameter ; otherwise expressed, perfectly round, clean and even in its dimensions and strength. This cannot be secured unless sought from the commencement. If the opener is fitted with lap attachments, the end must be kept in view from that position ; in all cases it must commence not later than with the scutcher. The chief point to be regarded is the method of feeding the cotton to the machine, as upon this depends a satisfactory result. There are two plans extensively in use ; the one being hand-feeding, and the other mechanical. Most persons regard the latter as the best plan, as it has been devised and invented to overcome the difficulties which a lengthened experience has shown to be inherent in the manual method. Where the latter is still in use, the cotton must be carefully weighed and evenly spread over a measured space of the travelling apron, or "creeper," as it is sometimes called. Unless this is regularly and conscientiously performed, the result will not please. It is important, therefore, that a thoroughly trustworthy person be secured, and placed in charge of this duty. The qualities required in a lap are an even thickness and width throughout, so that when delivered to the succeeding stage of carding no inequalities may be introduced into the sliver, owing to or arising from irregularities in the amount of cotton fed to the machine.

The scutcher is simply a repetition of the opener, but in which the lap-forming attachment is indispensable, whilst its parts are modified and arranged to do the work more perfectly, and to complete, in most cases, what the other has left undone. Like other machines in the cotton trade, it has undergone many changes before arriving at its present stage of comparative perfection. Makers now generally agree as to what should constitute its main features, differing only on points of detail.

Amongst hand-fed machines the Crighton is a well and

favourably known scutcher, and will serve for description. It possesses a lattice creeper with measured spaces on which the cotton, after being weighed, is evenly spread. A pair of small fluted rollers take the cotton from the creeper, and by their revolution pass it between them, when it comes within reach of the arms of a beater having two blades. This beater is enclosed within a cylinder, a quarter of the circumference of which, extending from the feed rollers to the bottom, is composed of a grid. As the beater revolves at the rate of 1,000 revolutions per minute, and has two blades, it makes 2,000 strokes per minute upon the cotton, being slowly delivered to it, and beats it down with great force from the rollers against this grid, causing broken leaf, motes, and other impurities to fall through. Extending along the bottom of the cylinder is a passage leading to the pair of dust cages, situated at the back of the machine. The exhaust fans induce a strong current of air, which carries the cotton from the beater cylinder to the slowly revolving dust cages, on the exterior of which the "lap" of cotton is deposited. The bottom of the passage, along which the cotton has thus been brought, consists of a lattice arranged with its surface open, so that any impurities that may have passed the first grids may be detected and removed at this point, falling into the cavities by their greater specific gravities. The lattice moves over three rollers arranged two above and one below in this manner—. . . The direction of its traverse is opposite to that of the cotton, which arrangement facilitates the extraction of foreign matter with a minimum loss of fibre. The lattice discharges the contents of its cavities into the receptacle for dust beneath the grid. The loose cotton is carried by the current of air to and evenly distributed upon the wires of the slowly revolving dust cages, the interstices between which are arranged so as to prevent the passage between them of the fibre, whilst permitting that of the fine particles of dust or sand that may yet remain in the cotton, or may have come

along with it on the current of air. From this part of their function which, though important, is only a secondary one, they obtain their name of dust cages. Their primary use is to receive upon their circumference the cotton floating upon the current of air induced by the exhaust fans in an even manner; by their revolution they join it into one sheet, which is removed by a pair of small fluted rollers that carry it to the compression rollers, whence it passes to the lap roller upon which it is wound. The lap roller rests upon two fluted rollers, by contact with which the lap roller is caused to revolve and to wind up the cotton in a continuous sheet until a thick roll is formed, technically called a lap.

As before remarked, regularity of feeding is of the highest importance in obtaining a satisfactory result. Too often, however, this task is relegated to a superannuated operative, or careless boy or girl, who can be hired for about ten thillings a week, whilst a trustworthy and conscientious attendant ought to have charge of the duty, and whose services would be cheaply purchased at an additional cost of five or six shillings per week. The former plan is, however, preferred from a mistaken notion of its greater economy, and reliance is placed upon subsequent processes for eliminating the irregularities and obviating the mischief to which it inevitably gives rise.

To prevent any tampering with, or loss of the weights from the scale, it is usual to make the weight end of the scale in the form of a canister, in which the weights are enclosed and locked. This is efficient as far as it goes, but it does not cover carelessness in putting too much or too little cotton into the scale. Only automatic weighing can obviate that. This could be accomplished without much difficulty if thought of sufficient importance. There is next, further, uneven spreading to be guarded against, and also the passage of the last portion of the feed of cotton through the feed rollers before another is supplied, which by inattention may occur and cause a very thin place, or even a break in the sheet of cotton forming the lap.

Besides the formation of an uneven sheet, as the result of careless or unskilful feeding, it will be found that laps vary in their weight, some being lighter and others heavier than what is required, without the cause being easily ascertainable. Of late years cotton, especially American, has been so inordinately charged with moisture, that when passed through the opener or scutcher, the earlier laps formed from the mixing will weigh more than those produced afterwards when the mixing has had time to evaporate a portion of its superfluous, and often fraudulently added water. Again, assuming that the raw material is quite dry, it so readily absorbs moisture in damp weather that, to some extent, a part of the variations occurring may safely be attributed to this cause, and the converse of this will be equally true; in hot dry weather the atmosphere abstracts moisture from the cotton, and the laps will weigh correspondingly less, though containing as much fibre as before.

The method usually adopted of obviating these irregularities is to weigh the laps as they come from the machine and classify them for the finisher lap machine, in which three, four, five, or six laps are combined as feed material from which the last or finished laps are made. The requisite number of laps are taken, the united weights of which shall average that of the new laps into which they have to be formed. By this combination or doubling, the irregularities of one lap are neutralized or minimized by those of the others, the outcome being approximately perfect—according to the theory; and which is probably true, even in fact, where the best attention is given to the feeding process by the operative in charge. But where this is not obtained, the result is not satisfactory.

To secure results as nearly as possible perfect, attempts have been made to dispense with the human factor in the problem, and make feeding as nearly as possible automatic. The lap-forming attachment has been added to the different forms of the opener, sometimes called the first scutcher.

In feeding the opener it is necessary that the cotton should be evenly spread upon the feed apron, in order not to gorge the machine ; but it is only seldom that it is deemed necessary to weigh the cotton and measure off the apron into yard spaces, as in the second scutcher. Where the best result, however, is desired, it is certain that this course would contribute to that end. The laps thus obtained from the opener, weighed, classified, and averaged for the scutcher, would yield a sheet far more level and free from defects as feeding laps than could easily, or possibly at all, be obtained from the hand-feeding described above. As such the laps obtained from the second scutcher would be as good in almost every respect as those hitherto obtained from the finisher lap machine, whilst the last mentioned being fed with almost perfect laps, would yield one much superior to anything usually obtained.

There is another method of precluding the defects of careless feeding and insufficiently opened or matted cotton. This is known as the lever or piano feed arrangement, so named from its being in principle similar to, and in its parts distantly like the arrangement of the keys of a pianoforte. The following Fig. 28 and brief description will clearly illustrate its principle.

Instead of the usual pair of feed-rollers for delivering the cotton to the beater, *a*, the bottom one is substituted by a series of bent levers, *c*, extending across the frame, and arranged as in the various positions in the diagrams A, B, C, in Fig. 28. The short ends of these levers are made different in form according to requirement, which is dependent upon the class of cotton, whether long or short staple, to be worked. The extremity of the long arm, *e*, of the lever terminates in a hook, by means of which it is attached to the rod, *f*. These rods are arranged vertically, and at the bottom end increase in thickness and pass between two horizontal bars, which are parallel to each other. Between the horizontal bars, and in the interstices between the rods, *f*, small bowls are introduced,

shown by the dotted circles, *i*, in the diagram c. The rod, *f*, on the right of this diagram, has a projection cast

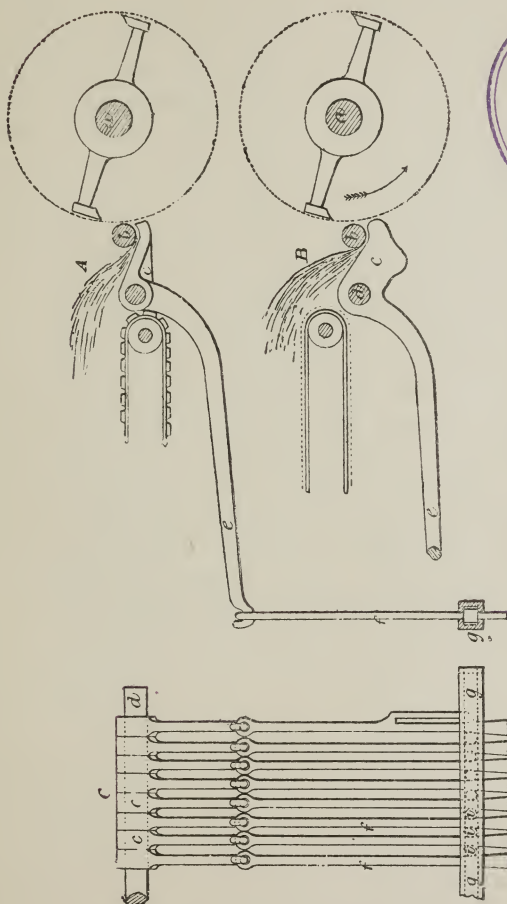


Fig. 28. Lord's Piano Feed; for Cotton Opener.

upon it, which forms with the other portion a slot for the reception of a connecting-rod attached to the levers,

the second of which is connected with the strap lever, *p*, seen between the cone drums in Fig. 29. The strap levers, *p p'*, are geared together by means of sector wheels; whilst *q* and *r* in the same Fig. are cone drums, and *s* is the strap by which motion is transmitted from one to the other.

The action of the different parts is as follows:—When the cotton is matted, or unevenly spread upon the lattice, causing a thick portion to go beneath the roller, *b*, the short end of the lever, *c*, is pressed down, which raises the long arm, *e*, pulling up the rod, *f*, the thick end of which coming up between the bowls, *i*, presses the rods in the only direction in which they can move, towards the slotted rod at the end, which through the connecting rod and levers described, moves the strap, *s*, upon the drums, *q* and *r*, and regulates the speed according to requirement—diminishing it when the layer is thick or matted, and increasing it when thin. The cone drum, *r*, actuates the feed-roller through the worm on its shaft. For obviating irregularity in feeding, whether arising from the attendant's carelessness, want of skill, or other causes, this arrangement has proved of considerable efficiency, and has met with a corresponding degree of favour from the trade. It can be attached to both the first and second scutcher, and can be easily adapted to the different makes of lap machines, so that if preference be given to one make over another on account of general excellence or specialities of detail, such preference can be gratified, whilst the advantages of this system of feeding is obtained.

The cotton having passed the opener and the first scutcher, now arrives at the second, otherwise called the finisher lap machine. The function of this machine is primarily to complete the cleansing process, so far as freeing the cotton from sand, dust, and the heavier forms of extraneous vegetable matter is concerned; and, secondly, to make the lap as even in the sheet as it is possible to procure from present appliances. The extent to which this is possible has already been indicated.

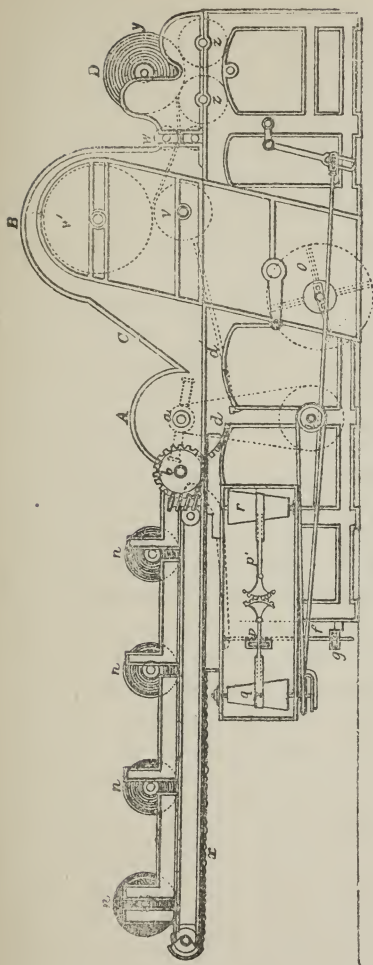


Fig. 29. Finisher Lap Machine with piano feed.

A finisher lap machine, with the evenor or lever feed-attachment, is illustrated in Fig. 29. The creel holds from four to six laps, u , which by means of the lattice apron, x , which revolves upon the rollers at each extremity of the creel, deliver a three, four, or six-fold sheet of cotton to the roller, b , and the series of levers which conjointly form the feeding arrangement just described. This in turn delivers the sheet to the beater, a , at a slow and uniform rate. The bottom of the beater-case, A , contains a grid, d , whilst a longitudinal grid, d' , extends to the dust cages, v v' . At c the casing is usually glazed, or a doorway formed, in order to permit inspection

of the interior. The former is far the best, as doorways cannot be made air-tight, and all defects of this kind interfere with the action of the exhaust draught, causing

it to deposit the cotton upon the cages in an unequal manner, so producing an uneven lap. As the cages revolve together, the cotton gathered upon their respective surfaces is formed into one sheet, and delivered to the compression rollers, *w*, passing which it is wound upon the lap-roller in the front or headstock, *D*, of the machine, and formed into, *y*, a lap. When the lap is completed, the machine is automatically stopped, the lap removed, the roller withdrawn and replaced in the machine to wind on another lap.

Well-made laps should be even in the sheet, level at the edges, uniform in length, and equal in weight. Any divergence from these points must be considered as defects likely to injuriously affect the final result. Every care should therefore be taken to see that this end is attained and carefully preserved.

Besides the points referred to as causing unequal laps, there are several in connection with the machines. The finisher machine, according to the received theory, makes a uniformly level lap from a number which are in that respect imperfect; the prevalent idea being that the inequalities of one correct those of another, though the chances are not few that a series of thick places in the different laps may fall together, and thus instead of correcting may intensify the fault; and similarly of the thin places. The majority of the chances, however, are considerably against this result. There is also the pneumatic factor in the problem to consider, the perfect action of which has much to do with obtaining satisfactory results. Should the fans be driven too slowly, the draught is insufficient to carry the cotton expeditiously to the cages, and the result is that some portion may be carried out amongst the dust and refuse which it is desired to remove. On the contrary, when run too swiftly, the current induced may bring with the cotton the lighter portion of the leaf, vegetable matter, and dust that ought to be taken out at this stage. When the proper speed is attained,

neither of these results can occur, the cotton after passing the beater being drawn rapidly to the dust cages, upon the exterior of which it is accumulated, until the layer becomes impervious, and the draught ceases to operate at that point; the cotton is then diverted to the uncovered portions of the surface, where it is still exerting its influence. It will be obvious from this that an even delivery of the cotton from the feed rollers will aid, but will not necessarily secure, the formation of an even lap, as this will quite as much depend upon the uniform strength of the current over the exposed surfaces of the cages. Should this vary appreciably in any portion from imperfections in the casing, or obstructions to its course in the interior, it will cause an uneven deposit upon the cages, and consequently an uneven lap. It is very important that these defects should not occur in connection with the finisher lap machine, as the pneumatic principle being dispensed with after that stage, a remedy for such faults is not easy to obtain in the subsequent processes, these only minimizing, but never perfectly removing the errors or defects of the preceding stages of the preparation.

A perfectly even lap is so desirable, and as yet is so far from being secured, that it might be useful to ascertain whether a nearer approximation could not be obtained by other means. With this consideration in view, attention may be drawn to an American invention connected with the woollen trade, which automatically takes up the wool, weighs, and uniformly feeds the scribbler—the machine in the woollen trade which corresponds to the lap machine in the cotton trade—in a perfect manner. That this has gained the highest approval of the trade is shown by its extensive adoption in America, and the favour with which it has been received in this country. It is known as the Bramwell automatic feed machine. In it the wool is put into a large box or case having a grating at the bottom for the exit of refuse,

and an elevating toothed apron in the rear covered with teeth of a peculiar construction. These raise the material out of the case until it is brought near the top, where it comes under the action of an oscillating comb, which has a slow but long sweep in front of the apron. This comb is armed with teeth, and operates in such a manner that the surplus wool is combed off the apron, and the rest left evenly distributed amongst the teeth of the latter. On the other side of the toothed apron there is another and a shorter one, having a more rapid movement. This is provided with flexible strips of leather, which sweep off the wool from the teeth of the first apron, and convey it in connection with a hollow or concave shell or dish into a weighing scale. This scale is formed of two curved wings, held together by suitable weights, and the whole suspended on steel knife edges and balanced with movable weights, which can be fixed to weigh any amount desired. When the scale has received the required quantity, it liberates a small trigger, which causes a projection to catch on one of the teeth of a revolving disc connected with an automatic clutch, which disengages the driving-belt operating the toothed apron, thus instantly stopping further delivery of material to the scale, which now remains at rest. When the proper time arrives the wings of the scale are opened, and the wool is deposited upon the feed lattice in a perfectly opened state, and in excellent condition for the cards. The scale is now closed, and returned for more wool; at the same moment the toothed apron is set going, and the delivery is carried on as before. While the scale is being refilled, the wool just discharged is carried along on the feed lattice to a fixed distance, leaving a clear open place for the next weighing to be deposited upon. The machine only occupies the same space as an ordinary feed-table, and while doing its work with regularity and perfection, dispenses with a great amount of hired labour.

There is nothing in this arrangement but what, with

proper modification, could be easily adapted to the cotton opener having a lap attachment, or to the first scutcher, and with manifest advantage to economy. We throw out the suggestion for what it is worth, and for the benefit of the trade, or those who may conclude it worth practical investigation. It might probably result in getting completely rid of a considerable difficulty, and even relieve the cotton of one process of scutching, in all of which it is severely treated.

When the laps have come from the finisher lap machine care should be taken that they are not damaged before being sent to the card. Much difficulty is often experienced in this respect. When the lap is completed, it is lifted from the machine, laid aside, and the roller withdrawn and replaced in the frame to wind on another lap. The soft mass of cotton forming the lap speedily closes up the space left by the withdrawal of the roller; and ordinarily when the lap has to be skewered again for the cards difficulty is experienced, time is lost, and considerable waste is made before it can be accomplished. To obviate these results Mr. H. H. Clayton, of Hyde, has invented and patented a simple expedient, which is thoroughly successful. In place of a solid lap-roller, he substitutes a tube roller, in which he inserts a long pin having a flat head of greater diameter than the roller. When the latter is withdrawn the pin is left in the cavity, retained by the head, thus preserving the bore, maintaining the form, and facilitating the handling of the lap, whilst time and labour are economized, and all waste from the stabbing of the lap prevented.

REMARKS.—At this point it may be useful to offer a few general remarks upon points which do not readily lend themselves to classification. In these the machinery demands the first attention. In willows, openers, lap, and finisher machines there are numerous makes, each having claimed for it some special excellence not possessed by its competitors. Into the details of the construction of

these we cannot enter except when they serve to illustrate some principle. When the latter is the case, and a machine is more fully noticed on that account, the reader is warned against drawing the conclusion that any special approval beyond what may be expressed is given to that particular make. Spinners in the different sections of the trade have their preferences for one design of machine over another, which preference may have a solid foundation or not according to the careful observation and skill of the person expressing it, or the uses to which he may put it. Some machines are better for one class of work than another, whilst few excel for all sorts. The qualities that ought to be looked for and demanded in all this class of the preparatory machinery is strength and simplicity in the working parts, each of which should be easily accessible for re-arrangement or repair. The blades of the beater should be so adjusted that they shall strike the cotton from the delivery rollers without breaking or otherwise damaging the fibre. The grids under the beater should have their first four bars placed about three-quarters of an inch apart, and the remainder half an inch. The beater of a machine working cotton from which it is intended to spin numbers between 12^s to 50^s or 60^s, should make from 1,100 to 1,500 revolutions per minute, the highest number being for the lowest counts. From 50^s upwards the speed may be from 800 to 1,100 or 1,200 revolutions.

The different machines should be evenly balanced in their various parts, all of which should be kept thoroughly clean and well lubricated in the bearings with good inflammable oil, not subject to becoming viscid or gummy. All dirt should be removed from under each machine every day, and the grids and cage wires ought to be kept perfectly clean, free, and open. The dirt flues and air passages should be cleaned at least once a week, or oftener when low dirty cottons are being used; the same remark also applies to the dirt chamber, which must be emptied at the same time.

The opening and scutching machinery of every mill ought to be of such proportions that every week it can be stopped, say at breakfast-time on a Saturday morning, so that the remainder of the working day, until one o'clock p.m. can be devoted to a thorough cleaning. Machinery of all kinds properly cleaned and lubricated requires less power to drive, yields a better product, and lasts much longer than that which is neglected in these respects.

CHAPTER V.

CARDING AND COMBING.

CARDING : its necessity ; its importance and purposes.—Development of the modern card, from Paul, Hargreaves, and Arkwright's improvements.—Description of the roller card.—Summarized statement of its functions ; how accomplished.—The process examined in its progress.—Methods of altering the work.—Extensive use of the roller card.—The self-stripping flat or Wellman card ; causes of its invention ; improvement in this country.—Dobson and Barlow's Wellman card.—The revolving flat card ; recent improvements.—Combination and other cards.—Card clothing ; for licker-in, main cylinder, rollers, clearers, and doffer.—Location of cards ; adjustment ; setting of rollers and clearers.—Double cards.—The Derby doubler.—Breaker and finisher cards.—Light carding.—Grinding ; by hand ; by machine.—Points of card teeth : needle point, diamond point, chisel point, and hooked point ; how to attain the good points and how to avoid the bad ones.—Differing estimates of the qualities of roller, flat, and revolving flat cards.—Cotton injured by overworking.—Severe treatment in the roller card.—COMBING ; indispensable for fine counts.—Invention of the combing machine ; description ; process of combing.—Improvement of the machine in England ; Dobson and Barlow's improvements.—Imb's combing machine for short staple cottons ; description.

IN dealing with the raw material, it will be remembered that it was shown that along with the perfect fibre growing from each seed, there was also a considerable proportion of imperfectly developed fibre which in the process of ginning is detached from the seed and mingles with the mature and perfect portion. Also from causes which need not be inquired into in this place, imperfectly developed, deceased, or insect-damaged seeds are found occurring in the pods. The fibre upon these will have been arrested in its growth, and, like the preceding, be deficient in length, substance, and strength. Instead of being white, cylindrical, and possessing the characteristic twist of the mature

fibre, it will be transparent, flat, and ribbon-like; often short and quite destitute of strength as compared with the well-grown fibre. The coarse impurities, such as foreign matter, vegetable substances, and seed, that have passed the gin, it has been seen, are mostly removed in the stages just described. These, however, have had but little effect upon the class of impurities now requiring notice, and which it is equally imperative to abstract in order to make good, strong, and even yarn. This is effected by the operation of carding.

Carding is probably the most important process in cotton manufacturing. It is the final stage of cleansing, wherein the minutest impurities foreign to the material, and all immature fibre, leaf, and broken seed, ought to be removed. To secure the cleanest yarn, however, requires the selection of cotton as free as possible from immature seed that has passed the gin, and which neither the opening nor scutching process completely abstracts, and which passing into the card gets broken up, when it becomes almost impossible to remove. The particles of these seeds are carried through the succeeding operations without being particularly conspicuous until the spinning process is reached, when in the twining the centrifugal force throws a portion of them off, whilst the remainder is retained on the surface of the yarn held by the short fibres upon them which having been spun into the thread. Sometimes in careless or defective ginning, when the gin blades rub against the grate bars, cotton is seriously injured by becoming "nepped": that is, the fibres are caught and rolled into little balls like grains of sand in magnitude, and which form a great defect in yarns when present in any quantity. Broken seeds and nepped fibres are difficult of removal in any stage of manufacture. In respect of these there is still room for the ingenuity of inventors to effect improvements. In other points, a well-constructed card is a fairly efficient machine.

The second function of the card, and the one which

ranks first in importance, is that of arranging the fibres of cotton in approximately parallel order. This is the first step in the construction of the thread. Up to this point every process has simply been preparatory, the fibres composing the lap, the product of the last process, lying across each other in a confused mass. But in carding, the sheet of cotton composing the lap is reduced to a thin cloud-like film or sheet of fibres arranged in almost perfect parallel order. This, as it leaves the doffer cylinder of the card, is drawn together, passed through a cone tube, thence between two pressure rollers, and by means of an ingenious mechanical arrangement it is received and automatically coiled in a can, in the form of a round, soft, untwisted strand of cotton technically called a sliver. It should be observed here that the coiler imparts to the sliver a very small amount of twist, but not so much as to appreciably affect the correctness of the preceding remark.

The modern card, like most other machines, is the outcome of the ingenuity of successive inventors. Its origin must be sought in the remotest times, and in the infancy of the textile industries. Probably its earliest known progenitor is the hand-card of the wool-comber, or the heckle of the flax-dresser, both of these probably suggested by the displayed fingers of the human hand. The growing demand for cotton goods in the early part of the last century induced several persons to attempt the invention of a more expeditious system, but little success for a time attended their efforts. Amongst these may be mentioned Lewis Paul of Birmingham, whose name is of some note as one of the early conjurors, as the first inventors and improvers of cotton machinery were in those days called. One of the most notable names in connection with the first successes in improvements in carding was that of James Hargreaves of Blackburn, the inventor of the spinning jenny. He introduced the stock cards used in the woollen trade into the cotton trade, and improved and adapted them to the manufacture of cotton. The changes he made consisted in

suspending one of the cards, by means of a cord passing over a pulley, from the ceiling of the room in which the carding process was carried on. This card he balanced by a weight at the other end of the cord, whilst its fellow he fixed upon the stock. By this alteration each stock was made to hold two or three cards, and each carder was enabled to card a greatly increased quantity of cotton. Soon after accomplishing this improvement, or about 1762, Hargreaves was employed by Robert Peel, the founder of the family which afterwards gave the eminent statesman of that name to the country, who resided in close proximity to the inventor at Oswaldtwistle, to make for him a cylindrical carding machine; which he succeeded in doing in a short time. This machine in its structure appears to have been the true parent of the modern card. In its first form it had no doffer arrangement, the carded cotton having to be taken off the cylinder by the hand-card, women being employed to perform the work. The inventor afterwards added a doffer, but it was not a success, consisting merely of a roller carrying a series of tin plates, which being made to revolve, scraped the cotton from the cylinder, and of course injured both the cotton and the cards. Though for a long time lost sight of, this idea has subsequently been rendered a practical success, as may be seen in the revolving doffer, now frequently preferred to the doffer comb. The invention of the latter is attributed to Arkwright. In place of Hargreaves' tin plates and roller, he substituted a thin blade of iron extending across the face of the cylinder. The bottom edge of this blade was serrated, and by means of a crank or eccentric a vertical movement of short range was imparted to it by which it was made to detach the cotton from the cylinder in a uniform and continuous fleece. This was the first doffer comb. In order to preserve the continuity of the fleece Arkwright invented filleting for card clothing in place of the sheets which up to then had been in use. The fleece was then contracted by passing it through a tube, after

which it was delivered into a can. From this time improvements succeeded one another at greater or less intervals, but the limits of space will not permit of these being traced to the present time. The sum of them, however, is the card as it is known to-day, and of which there are several varieties.

The first of these which calls for notice is the roller card. A section of this card with a portion of the side is shown in the accompanying illustration, Fig. 30. Its chief parts are the main cylinder, A, which at work has a surface speed of about 1,600 feet per minute; the licker-in, B, so called from its taking the cotton from the feed roller, C, and delivering it to the cylinder or swift; the small cylinder, D, is the doffer, whose function it is to take the carded cotton from the swift; E, the coiler; F, the sliver can; G, the lap resting upon G', the lap roller. Arranged over the main cylinder, and covering about half its circumference, are a number of small rollers, *r* and *s*. The former are carding rollers usually called workers, and the latter strippers or clearers. It is from these this card derives its name of the roller card. The licker-in, cylinder, workers, clearers, and doffer have their surfaces covered with card clothing, the fineness of which is varied according to the class of work to be performed.

Here we may briefly summarize the different ends sought to be obtained by the carding process:—

1st. The removal of all impurities, either natural or foreign to the cotton, which may have escaped the preceding processes.

2nd. The extraction of all immature, short, broken or nepped fibres, the retention of which would weaken or otherwise depreciate the quality of the yarn.

3rd. To disentangle the confused mass of fibres and place them side by side, or, in other words, in parallel order.

4th. To attenuate the heavy sheet of cotton forming the lap into a thin film or fleece, and to contract this into a ribbon or sliver fitted for the next process.

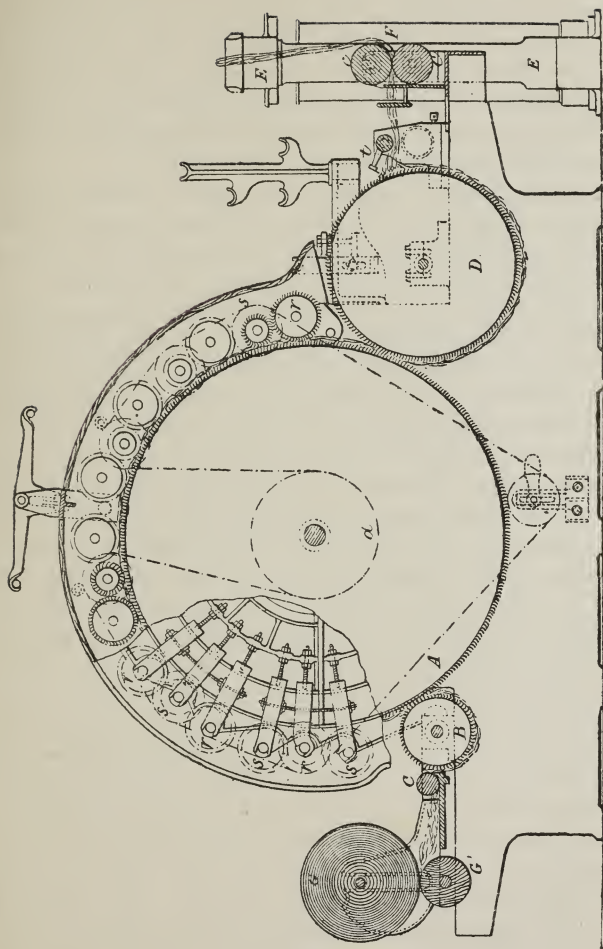


Fig. 30. Dobson and Barlow's Roller Card.

The first object is accomplished by the rapid revolution of the cylinder and rollers, which, striking the dried and broken leaf, seed-husk, or broken seed, fix and retain them in the card teeth. From this position they are removed either by hand or automatic stripping. Fine dust, not having sufficient material in which to hide away as it were, is by the centrifugal force exerted by the cylinder, thrown out, and falls through the grid at the bottom.

The short, broken, nepped, and immature fibres being of insufficient length to be held by the card teeth, and the latter being of deficient specific gravity, are driven off as "fly," and also fall through the grating to the floor.

The third and principal end sought, the arrangement of the fibres in parallel order, is accomplished by the process of attenuation and combing of the sheet of cotton forming the lap by the card teeth, which it undergoes in its passage through the card, which may now be described.

Reverting to Fig. 30; the machine having been supplied with a lap, G, the end is passed under the feed roller, c, and the machine started. The lap roller, c', slowly revolves, unrolling the web from the lap which, by means of the endless lattice on which it rests, is conveyed to the feed roller, c; this carries it within reach of the large roller, B, called the "licker-in," which, running at a surface speed of about 800 feet per minute, strikes the cotton in a downward direction from the feed roller, thus partially combing the fibres, and by its revolution carrying them to the large cylinder, A, which revolves at a rate of 1,600 feet surface speed per minute. Owing to this, and to the teeth in its clothing being bent in the direction of its revolution—which is upward at the point of contact with the licker-in—it strips all the cotton from the latter at the position where their surfaces are near contact. The cylinder carries the cotton forward to the first roller, which in most instances is a dirt or cleansing roller, revolving at a slow rate, say fifteen feet per minute. Its chief function is to gather from the surface of the cylinder all the rougher and

larger particles of dirt, motes, seed, leaf, husks, and neps left by the cotton which has been struck more deeply into the cards. The dirt which is thus extracted from the cotton is carried round by the roller and stripped from it by the attendant, or sometimes by a vibrating comb or stripper arranged for that purpose. The cylinder carries the cotton onward to the first roller, *r*, called a worker. Each of these workers has a companion roller, *s*, of smaller dimensions, called a clearer. These work in pairs. Being set in opposition to the main cylinder, *A*, their contact surfaces move in the same direction, but, as compared with the cylinder, at a greatly reduced speed. The card teeth of the worker are inclined the reverse way to those of the main cylinder, and owing to its slower surface speed, which is only about twenty feet per minute, the latter takes any cotton which is still entangled from it. The worker then carries this cotton over to the clearer; this roller running at a surface speed of about 400 feet per minute, and having its teeth inclined in the direction of its motion, strips the worker, and returns the cotton to the cylinder, *A*, which, owing to its greater speed of 1,600 feet per minute, is enabled to strip the clearer. The entangled portion thus gets a severe carding. The teeth of the clearer, it must be remarked, are inclined in the same direction as those of the main cylinder, *A*. Thus the cotton delivered to the cylinder, *A*, is carried by the latter in this manner in succession to each pair of rollers, after passing which, and being thoroughly carded in the process, it arrives at and is delivered to the small cylinder, *D*, called the doffer. This being set in opposition to the main cylinder, having its teeth inclined from the direction of its revolution, and moving at only a surface speed of sixty to seventy feet per minute, the latter owing to its greater speed deposits its cotton upon it. The doffer then carries it round to where its surface is subjected to the action of the doffer comb, *t*, fitted upon vibrating arms, which strips the thin fleece away. The movement of the doffer comb describes a small arc of the circle that would be formed by

the revolution of the vibrating arms upon which it is carried. It strips the doffer cylinder in its descent, and clears itself when ascending. It makes from 600-1,000 strokes per minute according to requirement, being actuated by balanced cranks. As the thin film of cotton leaves the cylinder it passes over a guide-plate and through a trumpet-shaped tube, in which it is condensed into a round untwisted cord. This, in its passage between the compression rollers of the draw box, is flattened into a ribbon, thence passes upwards to the coiler, E, and by an ingenious arrangement is coiled in the can, F, which stands upon a revolving plate. The cotton thus becomes a sliver, having its component fibres approximately parallel.

The attenuation of the sheet of cotton and its transformation into a sliver is thus completed, and we may pause a moment to examine the manner in which it has been accomplished. The lap, G, is unwound at a uniform rate by the lap roller, G', and is fed to the taker-in by the feed roller at exactly the same rate, these rollers being actuated from the same shaft. No difference of speed between these rollers can be permitted without derangement of work. If the delivery roller, G, moved with a greater surface speed than the feed roller, the lap sheet would accumulate in a heap behind the latter; were the reverse the case, the lap would be torn.

The delivery rollers supply the lap sheet to the taker-in at a given rate, say $1\frac{1}{2}$ revolutions = 9 inches per minute, in a specified time. The latter roller seizes this with its wire clothing, and owing to its great circumferential velocity, draws or attenuates it fully 1,000 times its first length. This will be seen from the respective dimensions and velocities of the rollers. The delivery of the lap sheet taking place at the rate of 9 inches per minute, and the rate of revolution of the licker-in giving a surface velocity of 800 feet per minute, this will be found to slightly exceed that number. It will be obvious that this must produce

a great effect upon the previously disordered state of the fibres forming the lap, and that in the direction of inducing a parallel arrangement. Still this sheet is far too heavy, and the cards of the main cylinder, which revolves at double the circumferential velocity of the taker-in, receive the cotton from the latter, and double the attenuation to which it has already been subjected. The cylinder having the heavier impurities on its surface, has these stripped from it by the dirt roller. The teeth of the dirt roller meeting those of the cylinder, and having their inclination against those of the latter, the impurities are caught and removed, leaving the cotton behind embedded in the cylinder card.

The cotton is next carried by the cylinder under the clearer, *s*, the bend of the clearer teeth not allowing it to take the cotton up, after which the insufficiently carded portion is immediately taken by the worker, *r*, and from this roller by the clearer just mentioned, by which it is again returned to the cylinder, having received a severe carding in its course. Thus the lap sheet is first attenuated about 1,000 times, the cylinder doubles this, the worker condenses it, the clearer recommences the attenuation which the cylinder completes, the next worker again condensing the film to the degree to which the first worker carried it, its clearer returning it to the cylinder as before. This process is repeated as many times as there are workers and clearers, until the cotton which composed the 9 inches of lap is all carded, or has its fibres laid parallel, when it is finally taken from the cylinder by the doffer, *d*, in a condensed form, its surface velocity being only sixty or seventy feet per minute. This will give a view of the carding or combing to which the material is subjected.

The doffer cylinder, in turn, is stripped by the doffer comb, *t*, whose action has been previously described. The cotton when combed from this cylinder appears as a thin film, which should be quite free from motes, broken leaf, seed and neps. It should also be uniform in its density: that is,

quite free from all "cloudiness." When the card is working well, and the preliminary stages have been properly performed, this will be the case, providing the quality of the material is of a fair average, say for medium counts of yarn, which is the class of material we assume to be under consideration.

The fleece as thus doffed is conducted over a guide plate on which it is condensed, and through a trumpet-shaped tube, and between the calender or compression rollers, *c*, whence it is carried up to the coiler and through its rollers. The sliver between the compression rollers and the coiler is subjected to a slight draught; that is, the surface velocity of the latter rollers exceed that of the former, gaining, say, about twelve inches per minute. This is called the drawbox draught, and it helps to perfect the parallel arrangement of the fibres which it has been the chief object of the carding process to attain.

The sliver now passes through the coiling disc into the can. This disc possesses a short tube, the upper opening into which is in the centre of the revolution of the disc, but which is not the centre of the disc itself, the tube extending therefrom in an oblique direction to a distance of about one-fourth the diameter of the sliver can. In its revolution it therefore describes and deposits the sliver in a circle between the circumference and the centre of the sliver can. The can being placed in a revolving dish, is carried round with the latter, which causes the circles deposited by the coiler to extend in a ring of circles, or rather of figures closely approximating thereto, around the centre of the can. This coiling also imparts a slight twist to the sliver, equal to about one turn in twenty-one to twenty-two inches.

The trumpet tube is fitted with a traverse arrangement, which moves it from side to side of the compression rollers in order to prevent the unequal wear of these that would arise from the sliver strand always entering at one place.

The work performed in the carding engine can be altered in two ways ; firstly, by changing the rate at which the sliver is delivered ; and, secondly, by increasing or diminishing the draught. The delivery of sliver is dependent upon the velocity of the calender rollers, and the speed of the doffer shaft from which the calenders are driven. The change is effected by means of a pinion upon the doffer cylinder shaft. Diminishing the number of teeth in this pinion lessens the delivery of sliver, whilst increasing them enlarges the length produced. The draught remains as before, because the feed rollers being connected with the doffer, any change made in one in a corresponding manner affects the other. The draught is similarly changed by altering the feed roller pinion, a diminution in the number of teeth lessening the speed of the rollers, and consequently increasing the draught ; whilst an increase reverses this. When the carding engines have been set to supply the drawing and slubbing frames, the delivery of sliver is seldom changed, as this would disarrange the relationship between the card and the machinery in the succeeding processes. Neither is the draught generally altered, as the object this would achieve can be equally well attained by altering the weight of the lap.

What is technically called "the draught" in the carding engine, is the difference between the length of the lap sheet and the length of the sliver formed from it. Thus, if 1 in. of lap is drawn into 100 in. of sliver, this would be termed a draught of 100 ; and a lap of 30 yards would, with this draught, yield a sliver of 108,000 inches.

The roller carding engine is probably the one most extensively in use, as it is the one best adapted for the production of low and medium numbers of yarn. It is comparatively simple in construction, easily set, and not liable to get out of order, whilst in its working capacity it excels all other forms. The work it performs, however, hardly equals in quality that obtained from either the Wellman, or the revolving flat cards.

The other two cards previously mentioned, the Wellman, so called from its inventor, and the revolving flat card, are essentially alike, the difference being one of detail only, relating to the method of stripping the flats. In both cases the main cylinder is covered on its upper surface by a series of bars extending across its face called flats, the under surfaces of which are covered with card sheets. The card surface is flat. When the series are brought together, they extend half way round the periphery of the cylinder. When laid in position their function is the same as those of the workers and clearers in the roller card just described. Instead, however, of revolving, in the Wellman card they are fixed in their position, only being occasionally lifted for the purpose of stripping from them the accumulated impurities.

The flat carding engine is of course one of the earliest forms of mechanical carding. Until, however, within a comparatively recent time, the cards were stripped by hand, this being an operation requiring both skill and close attention. With the growth of the trade and increasing scarcity of labour, a supply of the proper class of men became difficult to procure. This led to attempts to devise an automatic plan of stripping the cards, but only a small degree of success attended these early efforts. In the United States, where the pressure was most severely felt, the problem was approximately solved in the method invented by George Wellman. Cards, with his automatic stripper attached, have since been widely adopted in the trade, in which they are known as the self-stripping or Wellman card. As left by Wellman, however, it was not free from defects.

On its introduction into this country it was improved and modified by one of our leading firms of machinists, and adapted to work either as a first or breaker card, or finisher. Medium counts, say from 40^s to 100^s in warp yarns, and from 50^s to 120^s in wefts, require more carding than lower numbers. In many of these cases the roller card described is used as the first or breaker, and the Wellman or revolving flat card as the finisher.

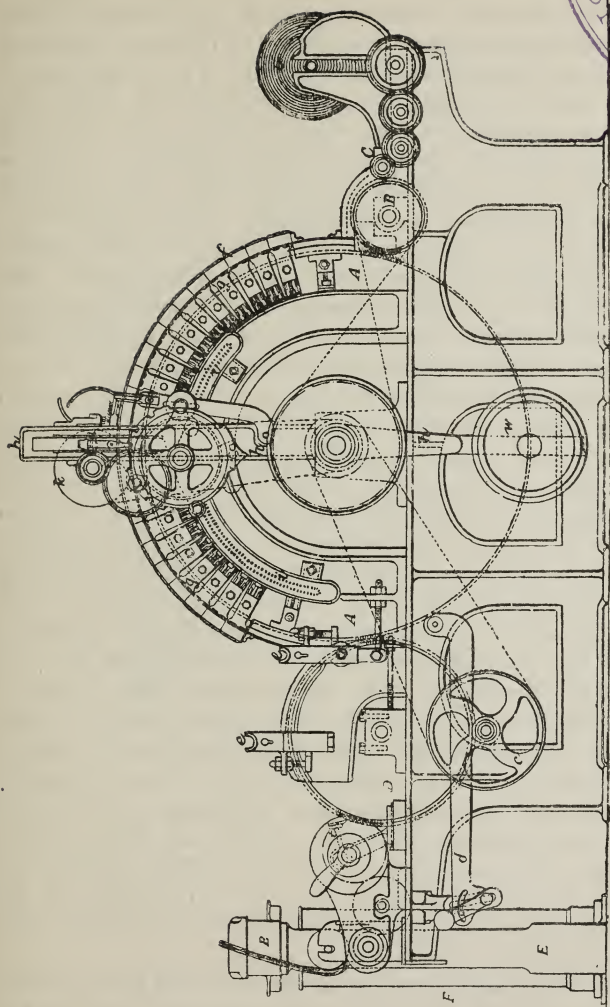


Fig. 31. Dobson and Barlow's Wellman flat Card.



The finisher carding engine on the Wellman principle, with the automatic stripper, as made by Messrs. Dobson and Barlow, the eminent machinists of Bolton, is shown in the annexed illustration, Fig. 31. In its principal parts it differs little from the roller card just described. The series of flats, *f*, which are bent concentrically over the main cylinder, are fitted upon adjustable brackets, *g*, and so arranged as to admit of each flat being set accurately parallel to the face of the cylinder. These brackets are carried upon a semicircle of firm, strong material, which is turned with great precision to the required shape. The lever or arm, *h*, moves backwards and forwards over the semicircle of flats, *f*, carrying at its extremity the flat lifting and stripping apparatus, which has proved to be a very ingenious substitute for human attention and labour. By its means the flats are lifted from their respective brackets, and turned upward with their face exposed to the action of the stripper roller, which clears away the accumulation of waste that has gathered thereon. Immediately this is done the mechanism restores it to its place; the arm resumes its movement, traversing the intervening space until the next flat is reached that requires to be stripped, when it again pauses, repeats the above performance, and so continues until the whole of the flats are stripped, when operations recommence. The order in which the flats are stripped varies, those nearest the lap requiring this attention more frequently than the others. The number of flats are always such that whatever may be the order of the arrangement of stripping, each in turn and proper rotation will come under the action of the stripper. The brackets, *e*, over the doffer cylinder and against the main cylinder, are for the reception of the grinding roller for grinding the cylinder and doffer without removal from the frame.

The revolving flat card is another form of this machine. In it, Fig. 32, the flats as seen are arranged in the form of an endless lattice: those in work rest upon semicircular

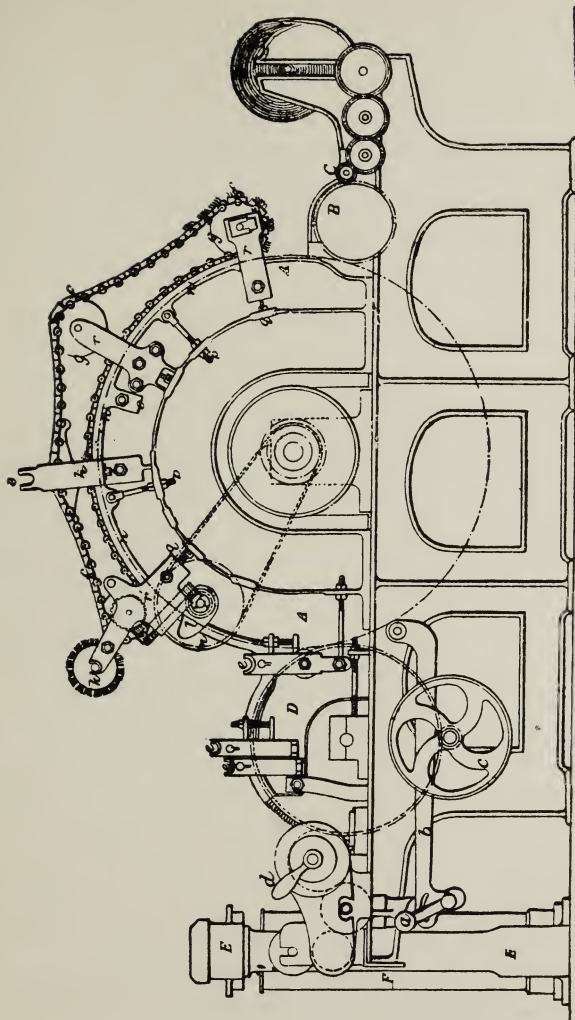


Fig. 32. Dobson and Barlow's Revolving flat Card.

guide rollers, *n*, carefully set upon the tops of the sides of the frame. These guides are adjusted by means of the screws, *p*. The flats not in action are suspended upon carrier rollers, *g*, over which they travel. The series of flats, as thus arranged, have a slow traverse, not more than one inch per minute. As they move, each flat in turn comes up to the stripping roller, *k*, by which it is cleansed from its accumulations of dirt. After this it passes upon the guides to take its place amongst the working flats. The other parts of the machine are similar to those of the Wellman card just described.

The three machines noticed represent the principal forms of the carding engine as now in use in this country. Besides these, however, there are several others, but which are mostly modifications wherein the distinctive features of the Wellman and the roller card are combined. These are called combination or union cards. The American cotton trade must be credited with several improvements, amongst them being the Wellman card and others which will subsequently come under notice. Within the last two or three years in that country, a new—or what is called a new—arrangement of the flat carding engine has been introduced to public notice, called the under flat carding engine, wherein the flats are increased in number to such an extent as to almost surround the main cylinder. Of the merits of this arrangement we cannot speak, and trustworthy information is difficult to obtain. Its novelty, however, is disputable, because an arrangement very similar in principle was tried in England thirty years ago, but was soon abandoned. The scale, however, on which the English machine was built was too large, making it cumbrous and unwieldy, and to occupy too much space. The inventors of its successor appear to have avoided this error. Its construction is, however, theoretically faulty, and in practice we think it will be found disadvantageous where the object desired is to obtain a good yarn.

It has been seen that the various rollers and cylinders of

the roller carding engine, and the flats of the Wellman and revolving-flat carding machine are covered with card clothing. This is constructed of bits of fine wire bent into the required form and inserted into a foundation composed of leather, cloth, or a composite material formed of two folds of strong cotton cloth, between which is a layer of india-rubber. Of late years leather, though perhaps the best material for the purpose, has, owing to its cost, been, to a great extent, superseded by the last-named fabric, which makes an excellent substitute. The wires are either flattened or round, coarse or fine, according to the purpose for which they are required. They are generally made in narrow strips about an inch and a half wide, and of any length that may be needed. Sometimes they are made in what is termed sheets, about six inches wide, and of a length sufficient to extend across the card cylinder. Filleting is carefully wound in a spiral manner upon the cylinders and rollers, being made fast at each end. Previously to its being used it ought to be exposed for several days, or even a week or two, in a room the temperature of which is uniformly equal to that in which it has to work when on the machine. This will probably be from 65° to 75° F., and its exposure in this manner will allow it to evaporate all its moisture, and shrink or expand as the case may be, so that when it has been wound upon the cylinders and rollers at a proper tension no further change will take place. The winding-on of the filleting or clothing of the carding engine is an operation of nicety, requiring both care and skill. In many districts there are people who do nothing else, who are called card clothiers, and go from mill to mill, wherever their services may be required. Quite recently, however, a machine has been invented by which this can be done with great accuracy, the fillet being held in such a state of tension as effectually to prevent any slack places occurring or any change of temperature perceptibly affecting it afterwards.

In Fig. 33 is shown the first card with which the cotton

on its passage comes into contact, that clothing the "licker-in" roller. This requires to be strong, in order that it may not be injured in the event of any hard substance which may have escaped extraction in previous processes passing between the feed rollers and coming into contact with it. It is therefore purposely composed of strong wire; the kind now generally used being flattened, and at the points it is cut diagonally at the required angle. This form of the tooth gives great strength and durability, with the smallest liability to injury. Its power is such that it will destroy or strike down almost any hard substance that may enter with the lap sheet, and that without material injury to itself, thus preventing damage to the fine clothing of the cylinder and rollers beyond. The illustration shows the form of the tooth, the manner of its insertion in the foundation, and the card curved on a section of the circumference of the roller, thus exhibiting it as when ready for work.

The next illustration (Fig. 34) represents the structure of a card used for the main cylinder when employed for good staple cottons. Cards are known by counts or numbers which are derived from the number of teeth in the square inch of surface. The drawing shows a card of 100^s, and slightly curved as when clothing the large cylinder and ready for work. The clothing upon the doffer cylinder is nearly always twenty counts finer than that upon the large cylinder. The dirt roller card (Fig. 35) is of a coarse wire, openly set, so that it will receive into its interstices the seed, leaf, motes, neps, and other impurities which the cotton may contain, and which it is its function to arrest and take out from the surface of the closely set cards covering the main cylinder. Its cut is similar in depth to that of the card covering the licker-in roller. The carding rollers, or workers and clearers, are both covered with cards of the same fineness, or nearly so, as those of the main cylinder. This also is shown as when ready for work.

Carding, as previously observed, is one of the most important processes occurring in the transformation of

Fig. 33.

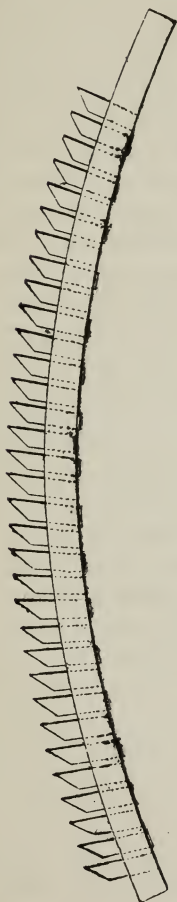


Fig. 34.

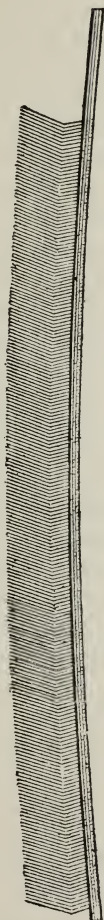
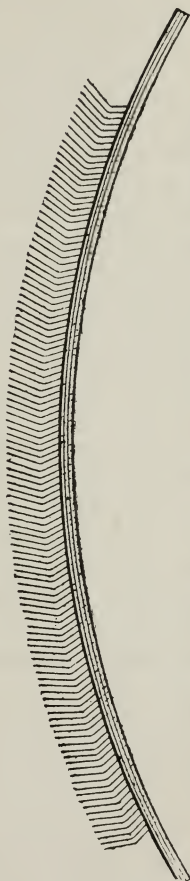


Fig. 35.



Card clothing for Licker-in (33), Main Cylinder (34), and Dirt Roller (35).

cotton into yarn. Whether this shall be done well or ill depends to a great extent upon the setting of the carding.

engine. It is meant by this that the carding engine should be placed upon a solid, or at least upon a firm floor, free from vibration and perfectly level, so that there may be no unequal pressure of the working parts upon the bearings and framework. A ground floor best secures this requisite, and it is still better if it be a room like a weaving shed, lighted from the roof. This secures a good north light upon all the working parts of the card, which, as it is the first machine in which the cotton is drawn into a sliver, it is important should be well done. It will also conduce to this end if there is sufficient room given to allow the work people to pass all round each machine. The surfaces of all the rollers should be carefully adjusted to that of the large cylinder, the cards whilst being set closely and evenly in each case, should in no instance be allowed to touch each other. The workers and clearers, in order to admit of this being done with the most perfect nicety, are mounted upon brackets on each side of the frame, and which are adjusted by screws. The flats of the Wellman card are set in a similar manner; whilst those of the revolving card are mounted upon flexible bends which admit of a very accurate disposition of the flats. Some persons set these parts by sight, turning the rollers round, and carefully observing that they are nowhere in contact. Others judge by the ear, and prefer this test to the eye, as the slightest contact can be heard by a quick ear. Others, again, prefer to set by a fine gauge, and probably this is the best and surest method that can be used when it is carefully employed. But all these methods require to be checked by close observation of results after the card has commenced to work. This is the best test of all and should never be neglected. It must always be borne in mind that the action of the card teeth is not the action of teeth working into one another, their function being rather to throw the cotton from the periphery of one roller or cylinder to another in a single sheet of fibres laid in parallel order, by means of which they can be stripped in a

continuous web and condensed into a sliver. If the wire teeth were so set as to work into each other, or even merely to touch, they would roll the cotton into lumps or neps, as they are called. This is also seen when a card is being overworked, or too much material being put through, which it rolls out in neps, however good the cotton may be.

Some persons prefer to use double carding engines, and these often very wide on the wire, say up to fifty inches. In these cards there are two large cylinders, the first being stripped by a doffer cylinder called a slow tummer, this in turn having the cotton taken from its surface by a clearer roller which transfers it to the second cylinder, after which the process is identical with that of the single card. In this case no second carding is needed. This plan is held to be economical as far as wages go, but it does not meet with the approval of many of the most experienced and skilful of spinners and managers, who prefer two processes through two single machines.

Where single cards are used, and the cotton is put through twice, the first card is called the breaker and the second the finisher. The sliver as doffed from the breaker is re-formed into a lap in the Derby doubler, the sliver cans being taken and placed at the back in sufficient number when combined to form a lap of the required weight and width, which is then ready for the finisher card. The clothing of the finisher card should always be finer than that of the first card. The first card is sometimes employed to perform the second operation, but this plan is not to be commended. This process, it will be obvious, secures much better than single carding a perfectly even sliver for the subsequent stages, and finally more even, uniformly strong, and therefore a yarn commercially more valuable, by which the extra cost of production will be more than compensated. Or if it be desired to produce a yarn not better, but equally good with that from single carding, it can be accomplished by using a slightly lower quality of raw material. In this manner compensation

for the increased cost of production is equally well attained.

Where this plan of working is adopted, the cards, both breaker and finisher, may be on any of the three principles already described: that is, both first and second may be on the roller, Wellman, or revolving flat principle; or, if desired, any two of them may be combined. In the latter case, the roller card or the Wellman are best adapted for breakers, and the revolving flat for finisher. In case the two first are used, the second should occupy the position of finisher.

Whatever class of machines is used, if good work is wanted, it is essential that they should not be overworked, that the carding should be what is called light weight. Where changes are made in the counts, reducing the numbers and increasing the production, there will as a consequence be a demand made upon the cards for a greater production; when this is the case, it may become almost imperative to work the cards more heavily. This condition requires great care from the carder. Light carding is easy enough, but heavy carding requires the closest attention of the carder, in order to prevent the cotton being delivered before it is sufficiently carded, by which bad work would result; and, on the other side, to prevent it remaining in the card a moment longer than necessary, as this diminishes the product. Cottons differ in the amount of carding they require, some needing more, some less; others, again, contain a larger proportion of short fibre, and fill the cards sooner, rendering it necessary to strip oftener. On changes being made in these respects, the carder should give the closest attention to his cards, in order that he may make any alterations that may be needed in time and before much imperfect work can have passed. To keep the product from the cards in the best condition, it must be kept in mind that when the weight is increased, it will be necessary to strip and grind proportionately oftener.

Considered in relation to good carding, grinding the

cards is a most important duty. To secure the best results the cards must be kept very sharp and free from all turning up at the points, by which "hooks" are formed. The best point for carding purposes is the diamond point, so called from its form. This is produced most successfully, and, indeed, only in perfection, by skilful hand-grinding with the flexible strickle. The form of this tooth is well known. No mechanical grinding has yet been able to equal the perfectness with which it can be obtained by the hand; nor has any other form of tooth been discovered which is so suitable for its purpose. Mechanical grinding with a roller extending across the face of the cylinder is objectionable because its abrading action is all brought to bear upon the back of the card-tooth, the effect being to produce what is called a chisel-point, that is, a wide flat point like that of the instrument from which it has been named. It will be seen that a fixed roller of this kind can have no other action, and consequently no other effect than to produce a point of this description. This is partially obviated, however, by the form of the grains of emery covering the grinding roller, and further by giving the latter a short lateral traverse. What is required is that the sides of the teeth shall be ground as well as the back, by which a true point will be at least approximately attained. The needle point would be the most perfect form of the tooth, but this it is well nigh impossible to obtain after the cards have their first or new point worn down. The needle point is produced by the revolution of the needle on its own axis when it is held against the abrading surface in an oblique line. This cannot possibly be done in cards after the clothing has been made. All that remains is to come as nearly to it as circumstances will permit. Skilful hand-grinding can come very near to it, as a careful and clever operator, fully knowing what is wanted, will grind round seven-eighths of the circumference of the wire forming the points of the teeth. This yields a point which is a little nearer theoretical perfection than

the diamond-point, though it is usually given that name. The Horsfall mechanical grinder, with its traversing disc, is the most successful invention yet introduced in attaining the end sought. This grinds the teeth not only from the back like the long roller, but also on each of the two sides. But the quarter of the circumference forming the front, and which in the revolution of the cylinders and rollers forms the face of the teeth, it cannot touch. Thus the diamond point is formed by grinding three-quarters of the circumference of the wire, the abrading surface having a three-fold action. But even this grinder, as usually constructed, is defective and imperfect, inasmuch as the width of the revolving strickle or disc on each side of the cylinders and rollers is imperfectly ground, or less perfectly so than the portion over which its traverse is complete. This arises from the fact that the strickle does not pass from the surface of the cylinder or roller before it commences its return, thus leaving the outer side of the tooth unground, which reduces the surface acted upon to one half of the circumference of the wire point. On the opposite side the reverse half is left untouched. With hand-grinding this does not occur. The reason why the front of the tooth cannot be ground, we ought to have observed before, is because of the angle at which it is bent. Were the teeth quite vertical, no difficulty would be experienced, as then the direction of its revolution could be reversed. It is, however, superfluous to say that were they set in this manner they would not be capable of doing the required work.

Practical men differ in their estimates of the value of cards built upon the foregoing plans, some maintaining that the roller card is the best, others strongly affirming the Wellman to be better, whilst others again claim that the revolving flat card is the best of all. It is not all practical men even who are best qualified to express an opinion on these points, as often their experience is not wide enough to enable them to judge of the merits of more than one of the three. Again, satisfied with what they

are doing, they have never inquired what is being done by others, and whether or not their own results are not surpassed elsewhere. During the past ten years, in which competition has become unusually severe, more attention than previously has been directed to secure the best results in quality and the highest economy in working, the effect being that opinion on this and several other matters has become more clearly defined. That this has caused the revolving flat card to grow in favour, as compared with its competitors, is indisputable, and there is little doubt but that this conclusion is a correct one.

It has been previously observed that cotton is injured by any overworking in the respective processes, and the fact cannot be too carefully borne in mind that it is improper and injurious to allow it to remain under treatment a moment longer than is necessary to effect the object of each particular process. It will be obvious also that the machine which accomplished this end the soonest and with the least amount of treatment of the fibres, will leave them in the best condition for subsequent processes, that is, with their natural structure and strength unimpaired.

To stand beside a roller card at work and watch its operations will convince almost any observer that the treatment to which the raw material is subjected is exceedingly severe, whatever may be the end to be attained; whilst the practical observer, knowing exactly what is desired, is driven to conclude that the violence is in excess of all requirement. The object sought being, in the first place, the extraction of all impurities, which consist mainly, if not altogether, of particles of dust, seed, leaf, and of short, unripe, imperfectly developed, and damaged fibres; and in the second, the arrangement of the fibres in parallel order; it would seem that neither of these can be effected in the most satisfactory manner by this card. Owing to the rollers being set as closely as possible to the cylinder without actual contact, the heavier impurities that are carried in with the lap, and thrown by the licker-in roller upon the

main cylinder, if not immediately taken off by the dirt roller in its revolution, are liable to, and actually are, cut to pieces by the succeeding rollers and clearers. When this is done, it becomes exceedingly difficult, if not impossible, to remove them afterwards; especially if they are the fragments of immature or imperfect seeds called "bearded notes." Great quantities of these are carried forward through all the succeeding stages to the spinning process, where they are spun into the yarn, being held by the short fibres upon them, whilst the specks of seed forming the base are thrown upon the surface of the thread in the manner previously described, disfiguring and deteriorating the quality of the yarn. This result is often seen where the roller card is employed, and its action in this respect is simply representative of what occurs in connection with other impurities in which the results are not quite so conspicuous. But the manner in which it performs the second function of the card, that of laying the fibres in parallel order, is not so perfect as is desirable. The transfer of the fibres from cylinder to worker, from worker to clearer, and from the latter again to the cylinder, and so on through the whole series to the doffer, from which it is taken by the vibrating comb, is not favourable to the disposition of the fibres in the desired parallel order. The alternations of surface velocity will have something more than a tendency to fold the fibres back upon themselves, and each roller, as it delivers its carded portion to the cylinder, will lay them in lines often not parallel to those of their proper direction. The best result, therefore, is only an indifferent approximation to the condition required. This necessitates considerable doubling, and especially drawing, which, in its turn, tends to destroy the natural convolute or twisted form of the fibres, which greatly weakens the yarn, because instead of firmly cohering when twisted together, a slight strain causes the fibres to glide over one another, the resistance offered to breakage being only that of about one-third or one-fourth of the fibres in the strand of yarn which happen

not to have been injured. That it has hitherto been impossible to utilize the full strength of the material employed is proved by the breaking strain of the best yarns that are produced falling far below the aggregate strength of the individual fibres they contain.

COMBING.—Combing may be described as the most highly perfected application of the principle of carding. Its chief purpose is to separate from the material all the fibres that are in length below the standard it has been decided to use. In addition, it effectually clears the cotton from vegetable and other impurities that may have escaped the carding process through which the cotton has first been put.

Combing is now indispensable in the preparation of cotton for spinning the higher qualities, and counts of yarn known as “high numbers,” and which range from 80^s to 250^s and upwards. It is, however, only used in the preparation of low or medium counts, say from 20^s to 60^s, in cases where a high quality is desired. Manchester and Bolton are the principal localities in which the combing machine is in use, though a few other establishments making specialities in yarn and using this process are scattered over other parts of the country. The large sewing cotton manufacturers use combed yarns in making their better qualities of sewings.

The combing machine was designed and invented by M. Heilmann of Mulhausen, one of the Continental centres of the cotton trade. This was a few years before 1851. It was probably an outgrowth of the same inventor's wool-combing machine. The cotton-comber, however, only drew public favour to itself very slowly. The inventor took the opportunity offered by the International Exhibition of 1851 in this country, to introduce it to the notice of English spinners. These gentlemen, or rather those of them spinning fine yarns, were not slow to perceive its value to their branch of the trade. A syndicate was formed to acquire the right to its exclusive use in England, and the patent was purchased for the sum of £30,000.

Its construction was placed in the hands of an eminent firm of machinists in Manchester, whilst its use was restricted to the members of the syndicate. After they had been fully supplied, and had enjoyed the advantages of its exclusive use for some time, it was permitted to be sold to the public under the imposition of a royalty of £300 per machine, which, with the cost of construction, brought the charge up to the considerable amount of £500 per machine. As the patent approached expiration this charge was reduced. The machine, however, was maintained at a high price, and the patent virtually prolonged, through the same process of protection being resorted to for securing the improvements that experience had dictated, and which, indeed, were almost indispensable to make it a thorough success.

The invention and adoption of this machine has had a highly important influence upon the fine spinning branch of the cotton trade. It has rendered feasible the use of cottons formerly regarded as quite unsuited for the production of fine yarns. By thus increasing the bulk of the material, and widening the area of selection, it has done much to reduce the prices of fine yarns to a lower level than before, thereby extending their application and increasing their consumption.

In the Heilmann "comber," of which Fig. 36 is a sectional view, the lap, *a*, was placed upon the rollers, *b*, which by their revolution unrolled the fleece when it passed down an inclined guide plate, *c*, to a pair of steel feed rollers, *d d'*, the lower of which was fluted, whilst the upper was covered with leather. These rollers had an intermittent movement obtained through peculiar gearing, by means of which they were turned one-sixteenth to one-twelfth of a revolution at a time. They delivered the cotton to a pair of nippers which opened to allow its passage. These nippers were composed of two parts, the blade, *e*, and the cushion, pivoted upon *e'*, the latter being covered with leather. The blade, *e*, received its movement from a cam at the gearing end of the machine. The motion was transmitted through two

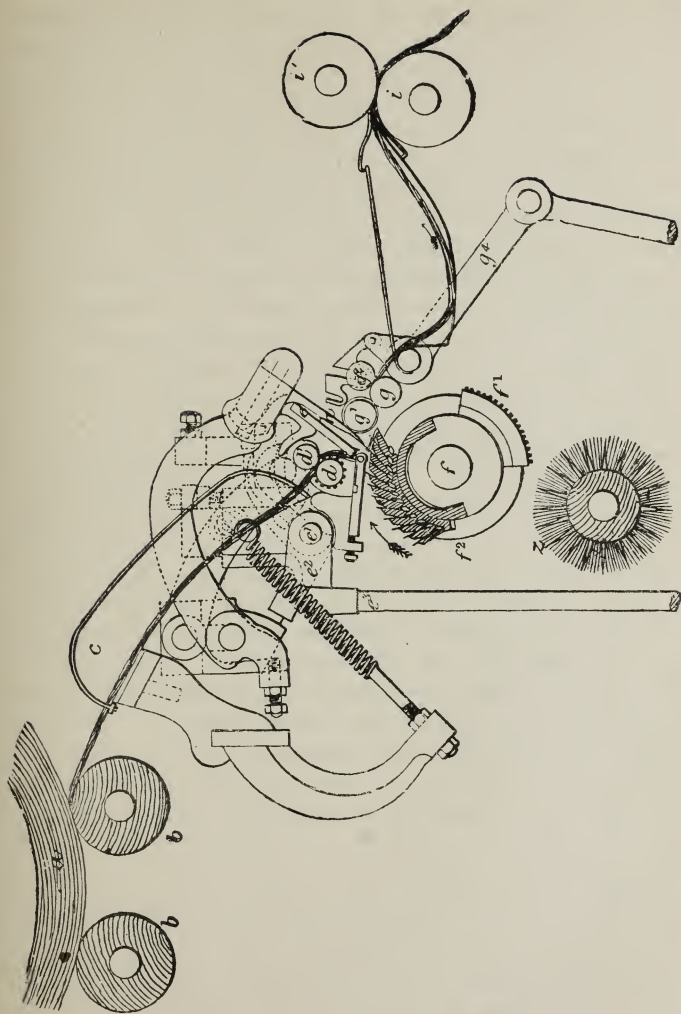


Fig. 36. Heilmann Comber. Section of working parts.

levers, a connecting rod, e^3 , and a shaft. The blade had a greater movement than was required to bring it into contact with the cushion plate, and the latter being hung upon a pivot, and held forward by a spring, was pushed backward by the pressure of the blade into a position which subjected the cotton to the action of the combing cylinder, f . A reverse movement then took place, which permitted the cushion plate and nipper blade to advance with the cotton in their grip to a point where, when the nipper blade, e , rose, the fibres were taken hold of by a detaching roller, g^1 , and a fluted segment on the combing cylinder, f^1 . The surface of this cylinder, opposite to the fluted segment, carried a series of seventeen combs, f^2 , graduated in fineness from thirty to ninety teeth in the inch. Between the fluted segment and the combs was a plain space at each side, during the passage of which in the revolution of the cylinder, time was afforded for making the required changes between the combs ceasing to act and the fluted segment coming into work, and *vice versâ*, the cylinder revolving continuously. The top comb was fitted above the cylinder, its function being to comb the ends of the fibres, and to prevent any being drawn forward except those that had been combed and cleaned by the cylinder. The top comb had only a vertical movement, being lifted out of the way of the cylinder comb when the latter was passing underneath. The detaching roller, g , and its leather covered fellow, g^1 , with the accessory roller, g^2 , received their motion from a cam which was arranged to turn the roller, g , one-third of a revolution backward; then, reversing, two-thirds forwards, when it stopped until the cylinder combs had prepared another length of fibre. The reverse movement was given to the roller, g , for the purpose of taking back the rear end of the previously combed fibre, so as to place them under and attach them to the fibres coming from the combs, whereby the whole were formed into a continuous sliver or ribbon, it being necessary to detach the fibres under operation from

the remainder of the fleece as fed in, and also from the fibres already combed. The attachment being made, the roller, g , was reversed, and removed the next length of fibres out of the way of the combs. In order to ensure a proper hold being obtained of the partially combed fibres, the top roller, g^1 , was made to move round the axis of the roller, g , into contact with the fluted segment, f^1 , of the cylinder, thus forming a revolving nipper. The top roller, g^1 , was brought into contact by the lever, g^4 , and its connections by means of a cam at the gearing end of the machine. It was in contact with the fluted segment, f^1 , of the cylinder, f , for only a portion of the time that the roller, g , was making the partial revolution forward, but it was always in contact with the roller g .

The process of combing being thus completed by these operations, the ribbon of combed cotton passed to the rollers, $i i^1$, through a trumpet tube which pressed it together to form a round sliver. The slivers from the six heads were then united, passed through the drawing head at the end of the machine, and coiled into a can.

The combing process having for its primary object the removal of the short fibres contained in the cotton, and, incidentally, dirt, leaf, and neps, it may be interesting to inquire how these were then disposed of by the machine. When the roller, g^1 , and the fluted segment, f^1 , of the cylinder had got hold of the front ends of the half-combed fibres, the top comb fell a little in front of the part upon which the cylinder combs had previously operated. The roller, g^1 , and the fluted segment of the cylinder then drew the fibres forward, the top comb preventing anything advancing, except the long fibres protruding through the teeth of the comb. The short fibres were thus left in the portion of the teeth from which the long ones had been drawn, and on the rollers, $d d^1$, delivering a fresh length through the nippers, $e e^1$, the combs, f^2 , on the cylinder, f , passed through the projecting part of the fleece, and separated from it the neps, dirt, and all the fibres not long

enough to be firmly held. They thus took the waste from the front ends of the fibre, and that which was left by the top comb. As the cylinder revolved the waste was cleaned out by the action of the revolving brush, *g*, which had a quicker revolution than the cylinder. The brush then threw the rejected fibres upon a doffing cylinder covered with card clothing, which in turn was stripped by an oscillating comb, when the waste dropped into a receptacle prepared for its reception at the back of the machine.

The short fibre and waste thus produced was subsequently used in the spinning of low and coarse descriptions of yarns, in which cleanliness was not an essential quality.

The Heilmann comber was left by the inventor as thus described, and in that condition at the time was regarded as one of the greatest triumphs of mechanical skill and ingenuity to be found in connection with the machinery of the cotton trade. Yet when put to work it was discovered that its numerous parts rendered it intricate, liable to get out of order, and difficult to set right. Many improvements, therefore, in the way of simplifying and perfecting its details were introduced during the course of the time covered by the patent. As these details were also successively patented, the protection originally granted was virtually prolonged. The original invention, however, became public property, and was adopted as a base from which to start afresh. Messrs. Dobson and Barlow, well known as eminent makers of machinery for spinning fine yarns, knowing the combing machine to have become an important, indeed indispensable adjunct or part necessary to complete their system of machines, took this in hand for purposes of improvement. Their establishment being situated in the midst of the fine spinning district of this country, they had the best opportunities of becoming acquainted with both its merits and defects. The latter it has been their study to remove. In the comber, as we have described it above,

there were in each set of six nippers no less than 564 pieces, including those belonging to their fixings. From this an idea may be formed as to its complicated character. These parts have been reduced to 216, showing a diminution of no less than 348 parts. In Heilmann's machines it took ten hours to set the nippers, which was a delicate operation, demanding the exercise of both care and skill. By the changes that have been made, this can now be performed in half an hour, and is so simple that any carder can easily and quickly be made to comprehend the method of doing it. The nipper has been reconstructed and made to hold the cotton to be combed against the fluted feed roller, thus dispensing with the cushion plate. The cotton is drawn into the top comb by detaching rollers, which draw it in a straight line from the grip of the feed rollers, thus combining great simplicity with efficiency. The working of the detaching rollers has been simplified, so that they can be stopped with greater accuracy, thereby ensuring a more equal delivery at each stroke. When changing the staple of cotton in the original machine, it was necessary to have two new large cams and a notch wheel. In the improved form, the makers have managed to dispense with these objections altogether. Combs must be perfect to do good work, and as they are liable to damage, great facilities should exist for replacing them quickly and easily; the latter have been much increased by the changes introduced. The different parts, formerly incapable of it, are now made adjustable, so that they can now be more nicely regulated, and all wear be taken up with facility. The connecting rods and half the joints have been dispensed with altogether, whilst two rollers can be set with one screw in front.

Instead of the waste, as formerly, being discharged behind into a receptacle, it is now deposited upon a travelling lattice, which conveys it to two calender rollers, whence it passes into a coiler at the end of the machine. These slivers are subsequently made into a lap, and used

in the ordinary way for spinning coarse counts. The improved comber can be adapted to work good American cottons, all kinds of Egyptian, Fijian, Sea Island, and all kinds of long stapled varieties.

But with all the improvements that have been effected, the comber on the Heilmann model remained rather limited in the extent or range of its use. It is only fitted for the longer stapled cottons, such as have been indicated. A want has, however, long been experienced for a machine of this sort, that should be capable of dealing with a greater variety, including those of short staple, and capable of doing a larger quantity of work. The want may be described as being for a comber that should take and do the work now performed by the finisher card, but in a better manner. Owing to the class of work which the Continental manufacturers are engaged upon, this want has been more strongly felt by them than by ours, and accordingly we find that attempts have been made to supply the requirement. The most successful of these efforts is that shown in a machine exhibited at Paris in 1878, which is the invention of M. J. Imbs. This, it is said, has met with extensive adoption on the Continent, amongst the manufacturers of France, Alsace, and Italy.

In the following, Fig. 37, a sectional view of this machine is given. The two rollers, A, have the lap, B, containing its rollers, placed in the position as shown, where it is retained by two stands. The revolution of these rollers uncoils the lap, the sheet then being conducted to the feed rollers, c c, and over the fixed rail, D, and thence between the nipper jaws, E, F, and the fluted rails, G, H. The parts, E, G, F, are connected with each other, and form the receiving and combing nippers, which are opened and closed at the proper moment by the action of the cams, K', and the rods, I, the jaws of the nipper, G, H, being attached to the latter. The cams, K, act upon the rods, J, to which all parts of the nippers are attached, and by this means the rod is moved backward or forward, or kept at rest, as

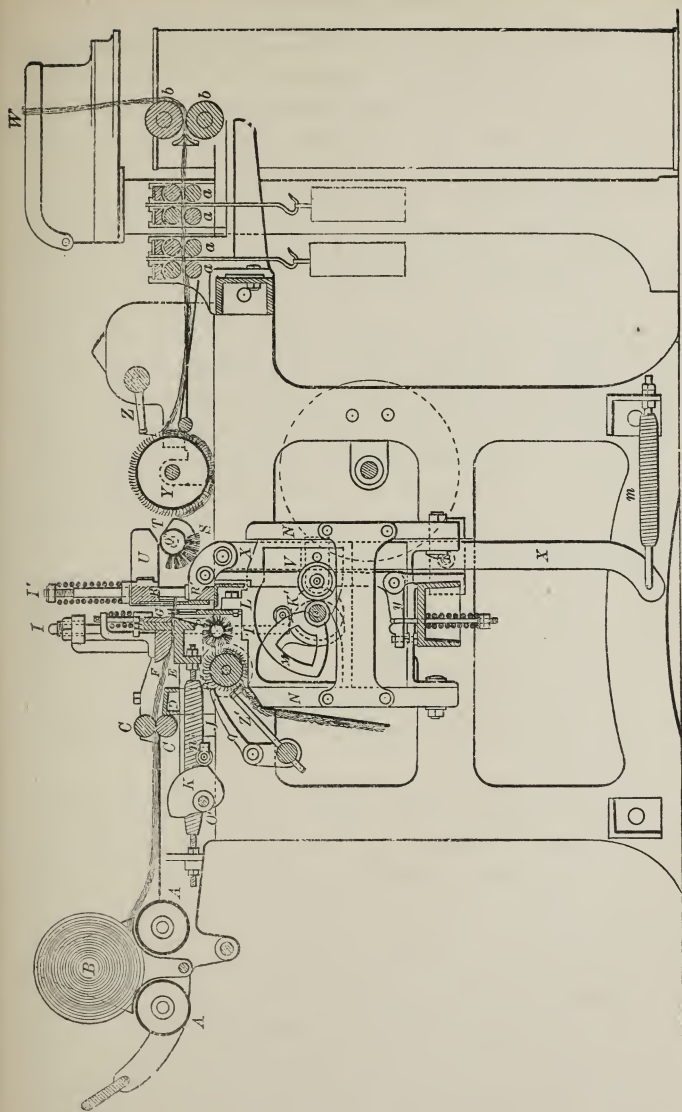


Fig. 37. Imbs' Comber. Section.

required; the springs, n , pull this rod back, whilst the shafts, $o\ o'$, make the same number of revolutions. The part, E , is covered with cloth and leather, and the jaws, G and H , are acted upon by the springs placed above them.

The two jaws, $R\ R'$, compose the delivering nippers, and are respectively connected with two large levers, $x\ x'$, which turn on their fulcrum, x , moved by the cams on the shaft, o , which act upon the friction bowls, v , attached to the levers, $x\ x'$. After the action of the cam has been completed, the spring, m , returns the levers, $x\ x'$, to their first position. The nipper jaw, R' , is fixed to the lever, x , whilst the jaw, R , can slide up the rod, i' , when the nippers are required to open, and descend again when they are to close. The delivery nippers are actuated by the cam, t , fixed on the shaft, o^2 , which turns on the bar, u . The shaft, o^2 , in its action makes the same and corresponding revolutions to the shafts, $o\ o'$.

The comb rod, p , is placed between the delivery and receiving nippers, and has an ascending and descending motion, pausing at the extremity of each. It is actuated by the cam, M , and the frame, L , which slides in the guide bars, N . The comb rod, p , contains from two to four rows of combs, which may be arranged to operate either together or in succession.

All arrangements being complete for work, the operation of the machine is as follows:—the delivery nippers, $R\ R'$, seize and pull through the combs a certain quantity of cotton, which then passes on to the brush segment, s , of o^2 , and is passed by its revolution to the doffer, y . The latter is arranged to oscillate, so as to receive the portions of cotton deposited upon it at regular and stated intervals. The receiving jaws in going back comb a length of cotton. When the combs descend they are cleaned by the revolving brush, q , which takes and deposits the waste upon the revolving roller, q' . During the descent of the combs, the receiving jaws descend with the sliver to the central line,

and the delivering jaws return to the same position open, again seizing and closing upon the proffered cotton; the receiving jaws are then opened, and recede in order to be fed anew. The combs next rise and again pass through the sliver, when the preceding operations are repeated. The vibrating combs, $z z'$, detach first the combed cotton, and second, the waste; the first named is formed into a sliver, and conducted between the four pairs of draw rollers, $a a$, and the delivery rollers, $b b$, thence to the coiler for deposit in the sliver can.

It is asserted that this machine does its work very well, both when dealing with long and short stapled cotton, getting through a great quantity, making a small amount of waste, and needing but little attention,—in these respects comparing favourably with the finisher carding engine.

CHAPTER VI.

DRAWING, SLUBBING, AND ROVING.

DRAWING: definition; its objects; doubling or combining slivers, minimizing irregularities; theoretical results.—Practical imperfections of doubling in past times; progressive improvement.—Extension of the process; causes of this.—The drawing frame: description; speeds of rollers; their action.—Details of construction.—Its development.—The electric stop motion.—Varieties of cotton.—Requirements in the drawing process.—Location of drawing frames; freedom from damp and draughts required.—**SLUBBING**: definition; description.—Intermediate, or Second Slubbing, a repetition of the preceding.—**ROVING**: definition.—Roving frame: description.—Differential motion of the spindles and bobbins in bobbin-and-fly frames, in the slubbing, intermediate, and roving frames; a nice problem in mechanics; Holdsworth's solution.—The principle explained and illustrated; successive layers; the traverse; winding of each layer; diminution of coils.—Spindles of the three frames.—Mechanism of the roving frame; connection between its parts; description; operation; the driving, roller, spindle, and bobbin shafts; jack in the box; the cones, method of operating them; the traverse movement; acceleration of speed.—Reversal of traverse and how obtained.—Traverse of the slubbing.—Doffing.—Altering draughts.—The intermediate, and the slubbing frames.

AS previously defined, in the process of drawing, several slivers, the product of the card, are combined and attenuated to the dimensions of one. Every step in cotton spinning has a twofold object—the first being to carry the material a little further in the constructive process; the second, to eliminate or minimize the defects of the preceding stages. The constructive part of drawing is to further perfect the parallel arrangement of the fibres contained in the sliver, which is accomplished by the different velocities at which the rollers revolve, and the proportion of which will be seen subsequently; the second is to render the sliver more perfectly uniform in its dimensions, or in

the number of fibres contained in a cross section, than it is when delivered from the card. As shown in the preceding pages, there are various causes tending to produce irregularities, not only between one lap as compared with another, but also in the sheet of an individual lap. In the one case there are differences of weight—some being too heavy, others too light, whilst a third part may be correct; in the other, the sheet will, or may, be in one portion too thin, in another too thick, and, again, may be of the proper texture. A small irregularity in the lap will be increased in the sliver coming from the card just in the ratio of the draft. Thus, suppose that one foot of the lap sheet, through some defect in the working of the lap machine or neglect of the attendant, contains only two-thirds of the proper quantity of cotton, this in the card will be drawn out to, say, one hundred feet of sliver, which will only be of two-thirds the proper weight. Were this to be carried through the succeeding processes, until the yarn should be completed, the fault would increase with every successive draft or attenuation of the material, though the relative proportion would not be altered. If we assume that the design be to produce a 40^s yarn, under this supposition the resulting part containing the fault would be 60^s, thus presenting the serious difference of twenty hanks. Error on the opposite side, in which the lap is too heavy, would produce defects quite as serious in making the yarn too coarse. This, however, rarely or never occurs in actual working, as experience has long ago demonstrated the necessity of doubling and drawing, by which its possibility is prevented. The parallel arrangement of the fibres in the sliver as it comes from the card is very imperfect, and must be improved. This could not be accomplished satisfactorily were the single sliver to be drawn, as the attenuation or reduction of “the grist,” as the dimension is called, would be far too rapid, and the object would be unaccomplished when the sliver had been reduced to a fine roving. Therefore it is that doubling is resorted to, which enables

it to be completed in a satisfactory manner, and the proper weight of the sliver to be preserved. But the second advantage, no less important, is gained by the almost entire elimination of the irregularities of the sliver, the necessity of which has been pointed out above. It will be obvious that the chances of irregularities falling together in a number of slivers are reduced in proportion to the increase of the number. And, similarly, an irregularity in one sliver, when combined with seven others which it may be assumed are perfect, will be reduced to only $12\frac{1}{2}$ per cent. of its original dimensions in its first passage through the drawing frame; in its second passage, this will be further diminished to $1\frac{1}{2}$ per cent.; whilst, in the third, it is practically obliterated. This process of doubling, looked at from a theoretical point of view, will yield a perfectly even sliver from the last head or passage; and this process is really the basis of the wonderful perfection attained in the production of an even thread, regular in dimension and strength.

When, however, doubling is looked at from a practical side, there are several imperfections discoverable which tend to prevent the attainment of theoretical perfection. In the earlier days of the modern system of cotton spinning, spinners were often troubled with the presence of "single" or weak lengths in the threads of yarn, which careful observation soon led them to discover was owing to the faults pointed out above. The cure was at once suggested, and doubling increased. The sliver, or rather the carded material from the hand-card in the days of hand-spinning, was always used with little preparation in the shape of drawing or doubling, all the process of attenuating and equalizing the mass of fibres being performed by the fingers of the spinner. A coarse rove was first made from the carded cotton, and this by a second process was reduced and spun into yarn. The roundness and evenness of the thread thus formed was a test of the qualifications of the spinner, whose productions commanded a corre-

spondingly good price, or otherwise, as these points were more nearly or distantly approached. On the displacement of manual spinning by that of machines, it was found that the latter, not possessing human sensitiveness, had no power to correct any irregularities in the sliver, but that they attenuated them in exactly the same proportions as those of the draughts, whether the faults were an excess or insufficiency of weight, and that the yarns thus produced were considerably inferior to those obtained from good hand-spinning. It was therefore a happy thought to correct the inequalities of the slivers by putting two of them together, and drawing them into one, for the practical development of which plan the trade is indebted to Arkwright. It was a natural outcome of his realization of Paul's great conception of attenuating the roving by mechanical means before twisting it into a thread. The result was a great improvement, which showed that this was the way to comparative perfection, and it was quickly followed. Putting up two slivers, and drawing them into one, was literally "doubling," from which the name of the process has been derived. Though very satisfactory, this left much to be desired. Three slivers were afterwards treated in the same way with advantage, which were subsequently increased, until, as now, six to eight were put up in the first passage through the drawing frame.

Whilst these changes were in process, the passages were at the same time being increased, until the material was put through the drawing frame three times, as is now the case ; but, after all this, it was found that imperfections yet remained to be remedied. The drawing heads delivered the slivers into cans placed beneath, which were neither supplied with coilers nor pressers. The consequence was, that the slivers were quickly overflowing if neglected for a moment or two by the attendant. The duty of the latter was to keep constantly on the move from one machine to another, supplying fresh sliver cans to the back of the frame as those already there became exhausted, and

pressing the sliver down in the receiving cans at the front until they were properly filled. This system not only entailed much waste, but, as will be obvious, led to frequent damages of the sliver. Careless and thoughtless attendants, in pressing it into the cans, had little regard to avoid dragging it, thus making thin places, or breaking it, and making bad piecings. Too often, also, one or more of the sliver cans were permitted to become exhausted, and the end to pass through, perhaps a long distance, before its exhaustion was observed. This weakened the new sliver to the extent of one-eighth, or other proportion, of its strength, and sometimes even more. The defective portion was then either allowed to pass, or was pulled from the cans, and made into waste. Many of the elder employers and operatives of the present generation will remember this state of matters generally prevailing. Whilst spinning and manufacturing were combined in one establishment, not much importance was attached to the defects in yarn arising from these sources. When, however, the two branches began to separate into two distinct businesses—the spinner having to sell his yarn, and the manufacturer to purchase it—the latter lodged complaints when the defects became unduly numerous, and sometimes adopted more stringent measures to obtain redress, such as claiming compensation for inferiority of quality, rejecting deliveries, cancelling contracts, or severely leaving alone an inferior spinning. These courses of action quickly stimulated spinners to investigate the causes of defects, and to take steps to improve the quality of their yarns, as by so doing they enhanced their reputation and obtained better prices. It is to promptings from this source that the trade is indebted for many of the improvements that in their aggregate effect have carried the art of cotton spinning a long way towards perfection. The automatic presser, which gently presses the sliver, without injury, into the cans; the coiler, which causes it to be deposited in a beautiful order that precludes its entanglement; and

the automatic stop-motion, that immediately on the exhaustion or breakage of a sliver, and before the end can pass between the back rollers, and injure the new sliver being made, stops the machine, and refuses to permit work to be resumed until a new sliver is put up, owe their origin to this cause. A stop-motion in front also exercises similar care in the prevention of overflowings of the can, thereby avoiding the making of waste. As long as the drawing-frame is kept in good condition, and not otherwise tampered with in the stage of perfection to which it has attained, it automatically makes almost perfect work. That it should accomplish what we have stated proves it to be one of the triumphs of mechanical skill, and shows to what a wonderful extent inert matter can be endowed with what might almost pass for the reasoning faculty, the highest attribute of the human mind.

Though the merits of the drawing-frame entitle it to be spoken of thus highly, yet it is one of the simplest machines employed in cotton spinning. It is the first, however, in which is introduced the important principle of drawing or attenuating the sliver by means of rollers. The size of these machines is usually indicated by the number of heads or deliveries they contain, as they are made in different dimensions, according to the requirements of individual spinners. One head or delivery constitutes a perfect machine; but the usual custom is to combine three heads in one frame, when it is called a drawing-frame of three deliveries. As will be seen from the accompanying illustrations (Figs. 38, 39, 40), which show the front and back elevation and section, it consists of an oblong frame, in which is mounted a roller beam, carrying four rollers, extending the length of the frame. These are the bottom rollers, and contain twice as many fluted bosses as there are heads to the frame. The top rollers are short ones, though double bossed, being of a length to serve one head only. They are mounted in the same bearings, and rest upon the bottom ones. The top rollers are all plain,

unlike those on which they rest, and have their bosses covered either with flannel or leather. Formerly the first and second top rollers from the back were corrugated, but this plan has been very generally abandoned. A top and a bottom roller form a pair. The upper rollers are driven by contact with the lower ones, which is maintained by saddles or hooks, from which weights, *v*, are pendent. A light wood clearer-roller rests upon the top of each pair of rollers, whose function is to take up any loose fibre or broken sliver, to prevent it running round the rollers, the diameter of which it would quickly increase at the point, and so prevent the roller drawing properly in any other part of its length. Waste can be stripped from the clearer rollers with more facility than from the drawing rollers.

The speed of each pair of rollers differs from the other, being graduated from the back to the front. The usual speeds are in the following ratio: the back pair or taking-in rollers, 1.00; second pair, 1.25; third pair, 1.75; fourth, or front pair, 2.75. It will thus be seen that the acceleration is not in an equal ratio, the second pair revolving at a rate only once and a quarter as fast as the first, or taking-in rollers, whilst the third pair gain half a revolution upon the second. It is between the last two pairs in the series—that is, the third and fourth pairs—that the chief draught takes place. The difference between the speed of the third and the fourth pairs is considerable, the acceleration of the latter being more than one-half. Thus the real work of this machine is done by the second, third, and fourth pairs of rollers, the first pair being conductors, taking the sliver into the machine, and retaining it for a little preparatory drawing by the second pair. The latter hold the material, whilst the third pair attenuate the sliver still further, the operation being concluded by the last pair. The top rollers not being fluted, but covered with leather or flannel, give the surface a chance of sliding over the portion of the material that may be too firmly held to be drawn from the preceding rollers. This to some extent prevents the breakage of the longer

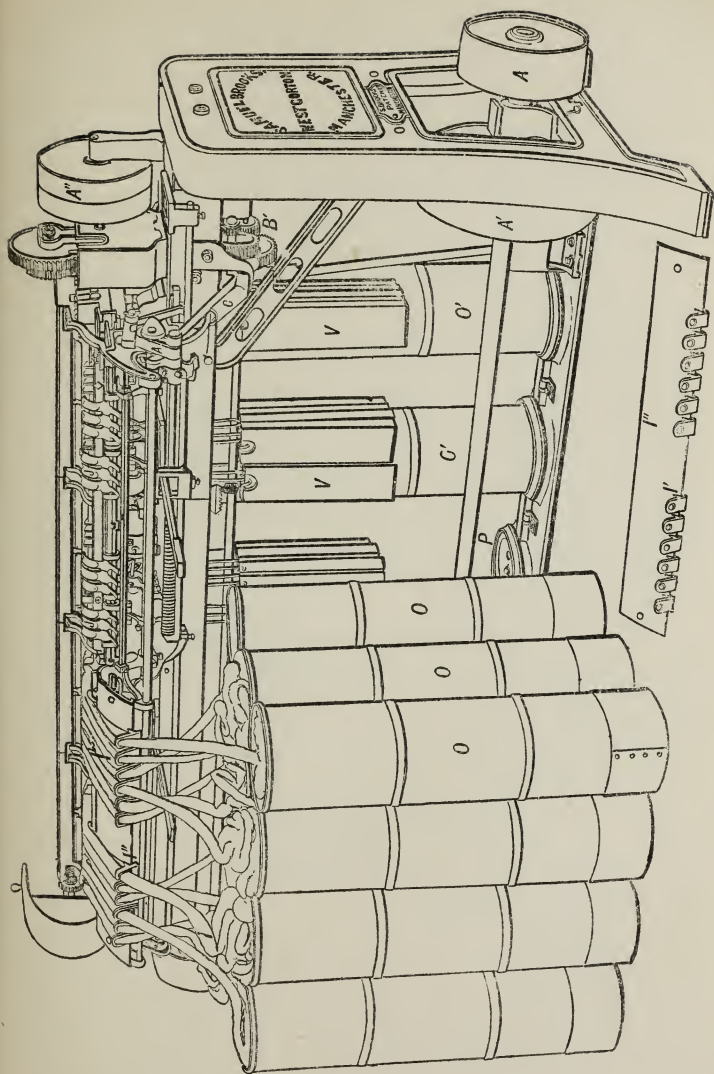


Fig. 38. Drawing frame. Back view.

fibres that occur in the material. In all cottons there is a variation in the length of the fibres, some exceeding and some falling below the average. The rollers are always set to work the average length, whilst that portion which much exceeds it gets broken in the drawing, or escapes such a fate in the manner indicated. The draught upon the cotton in this position is such that the fibres are not only changed in their relationship to each other, but their arrangement in parallel order is greatly advanced. The front or fourth pair of rollers having only a very slight gain upon the speed of the third pair have as their function little more to do than take hold of, and conduct the sliver to the point at which it is delivered. After the sharp action involved in drawing there is a crispness or tendency to curl in the fibre, and the delivery rollers exercise a useful function in slightly calendering the sliver, thereby preventing it from flying from the position into which it has been the object of the process to place it. This brief description will fully explain the principle of the machine, and the purpose for which it is introduced into the series necessary for transforming cotton into yarn.

It will now be proper to give a more detailed description of this machine, as illustrated in the accompanying drawings, Figs. 38, 39, 40. The sliver cans from the card are arranged behind, as shown in Fig. 38. The slivers, 1, from them are passed upwards through guide holes, 1', extending the length of the frame. The function of this is to prevent the sliver being drawn into the rollers in knots, kinks, or an otherwise entangled condition. Emerging from here they pass over the polished convex surface of a guide-plate, 1'', to the spoon levers, J, which form a portion of the ingenious arrangement for stopping the machine when a sliver breaks or becomes exhausted. The opposite end of this lever in some machines extends backward beneath the convex guide-plate just mentioned, and has a pendant or tail-piece jointed to it. The whole is then nicely balanced in the centre on a pivot, or, as in more

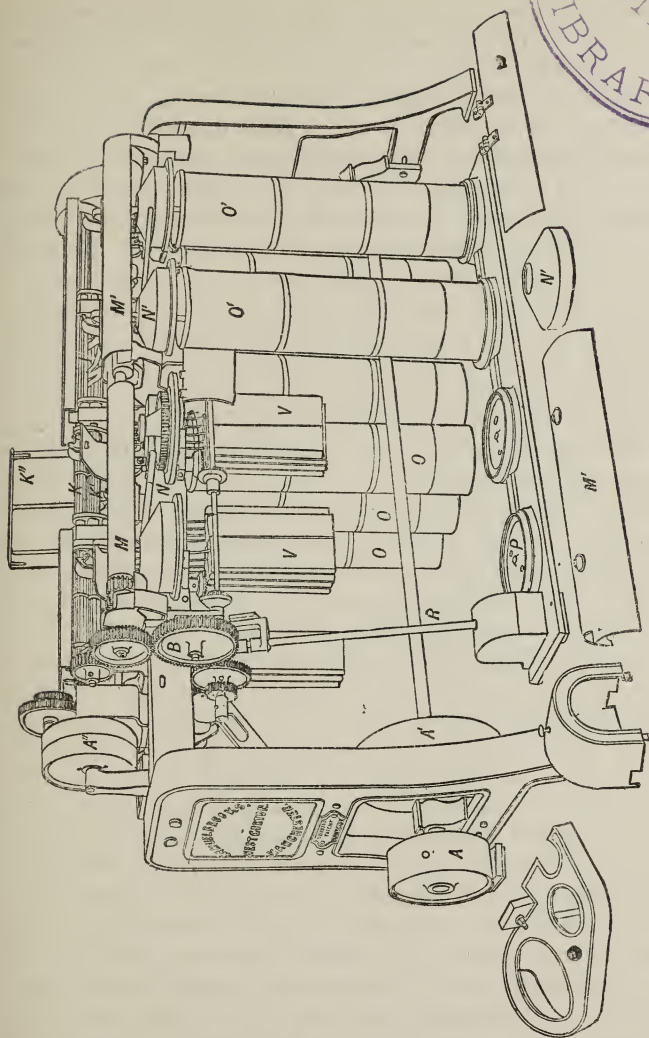


Fig. 39. Drawing frame. Front view.

recent machines, on a knife edge, which is more sensitive, with the inclination slightly on the side of the tail-piece. The illustration is of a machine of the latter kind. In actual work, the passage of the sliver through the spoon forming the head rather more than counterbalances the slight difference of weight in favour of the rear end of the lever, and holds it up. When, however, it breaks or becomes exhausted, the latter drops, and the tail-piece falls into a position where it arrests the oscillation of the shaft, F, causing the lever, D, to lift from the fulcrum point, E', into a fresh position, from which it swivels the tumbler catch, G, into the position shown by the dotted line, which releases the strap fork rod, and stops the frame, which cannot be started until the sliver is pieced, or another supplied. Leaving the spoon the sliver passes over another guide-plate on its passage to the rollers whose functions have already been described. Emerging from these, it passes between a pair of calender rollers, which compress it into a ribbon form, and deliver it to the revolving head of the coiler, such as described in connection with the card, by which it is neatly deposited in the slowly revolving can. The back stop-motion is to prevent the formation of single in the sliver; but there is also one in front by which waste is prevented. In ordinary machines, before passing the calender rollers, the sliver is conducted over the head of a double lever, the rear part of which extends to the back of the machine. This part is fitted with a movable weight, that can be set at any desired point, which enables the lever to be easily arranged in such a position that the passage of the sliver over the opposite end shall elevate the weighted end. The breakage or removal of the sliver therefrom at once allows the latter to drop, when its extremity falls into a like position to that of the pendent bar of the back stop-motion, and arrests the revolution of the same shaft with a similar effect. In the one under illustration this end is obtained by a different arrangement, as will be obvious

from the following brief details of its general mechanism and operation. The first motion shaft carries the pulley, A, by which it is driven from the line shaft. A strap upon the pulley, A', extends upwards, and drives the fast pulley, A'', upon the fluted roller. This roller carries a pinion, which gears into and drives the first of a train of wheels, B (Fig. 40), actuating the eccentric wheel, B', to which is attached the connecting rod, C, coupled to the lever, D, the latter being in turn connected with the motion box, E, by

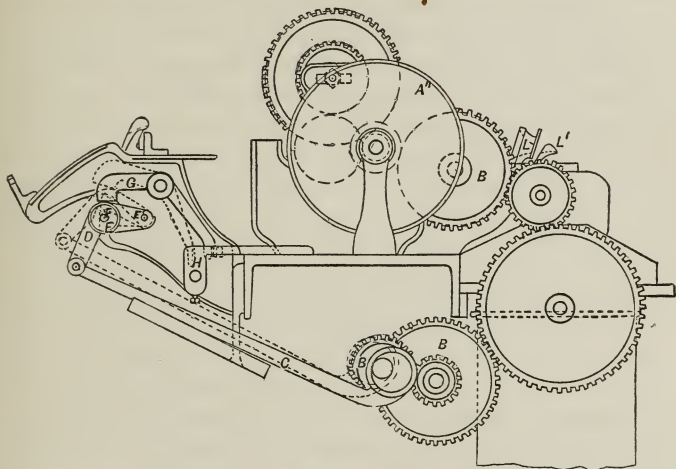


Fig. 40. Drawing frame end.

means of the stud, E', the box being keyed on the shaft, F. One end of the tumbler catch, G, extends to and rests upon one end of the lever, D, whilst the opposite rests in a notch in the strap fork rod, H. When the sliver breaks at the lever spoon, L', it falls, and acting through a connecting bar and lever, stops the shaft, F, as in the previous case.

The drawing frame has attained its present degree of perfection very slowly. For a long time it was impossible to overcome the difficulties above described regarding the occurrence of "single," though on every side numerous

attempts were being made. James Smith of Deanston, in Scotland, well-known in his day as a skilful spinner and a successful inventor, was the first to secure a measure of success by the invention of the stopping arrangement just described. It has been improved and perfected in several details by succeeding machinists, who have now obtained with it a very sensitive action. In the case of the machine which the accompanying drawings illustrate, the spoon levers are balanced on what is technically called by mechanics a "knife edge," which secures a remarkably quick action and a prompt stoppage of the machine.

Messrs. Howard and Bullough, Accrington, have introduced an electrical stop-motion, which has been successfully applied to the drawing, slubbing, and intermediate roving frame. Its application to the carding engine and the final roving frame has not been so satisfactory, and the makers do not recommend it in these cases. Briefly stated, the invention consists of the introduction of a small magneto-electric machine, which is driven by a band or belt from the shafting driving the machinery. It is very small, and requires little power to drive it. Two rods convey electricity from the generating machine to the frame, to each of which certain parts of the machine are connected; but the circuit is not completed. The drawing frame requires to be stopped on the breakage of the sliver at any part, or its exhaustion, on its lapping around the rollers, or on the can becoming full. The insertion of the sliver between the rollers slightly elevates the top roller, and prevents the completion of the electrical circuit. Should breakage or exhaustion of the sliver occur, the slight space separating the two parts is immediately closed, the circuit completed, and the machine stopped. In the event of the sliver lapping around the rollers, either top or bottom, the top roller is raised, and brought into contact with a screw, which also completes the circuit, and stops the machine. On the can having become full, and risk occurring of the sliver running to waste, the latter is prevented

by an arrangement which allows the accumulating sliver to lift the tube or coiler-wheel, until it comes into contact with a projection from the calender roller cover, which again completes the circuit, and stops the machine. These stoppages are effected by the introduction of a small magnet, arranged near a small pendent lever, whose function is similar to that of the tail-piece of the spoon-lever stopping arrangement. This magnet does not become operative until the completion of the electrical circuit, when it attracts the pendent lever towards itself, which brings the lower extremity into contact with the notched revolving shaft, and through the arrangements already described in connection with that part, stops the machine. The introduction of this subtle agent into mechanical industry places a new power in the hands of our machinists, which may help in the early future to solve some difficult problems.

The varieties of cotton differ greatly in their nature, some being harsh and intractable, yielding only slowly to the necessities of manufacture. Others, again, are soft, silky, and very flexible, and are easily brought into an orderly condition. The former require the most drawing, and even after such treatment do not often yield a solid, strong yarn. Their intractable nature indicates the use to which it is best they should be put, and that is for the production of weft yarns, or warp yarns that are to be subjected to heavy sizing. They make a soft, spongy yarn, not well consolidated, very suitable for weft, which is required to give a full and substantial appearance to fabrics technically called "cover," and which can be obtained more easily and cheaply by the employment of a full-looking weft than one in which the fibres are more tractable, and the thread more nearly solid. This is a useful quality, again, in warp yarns which are designed for heavy sizing, as when the thread is wanting in solidity, the materials employed for sizing can easily penetrate and fill the interstices, whereby the yarn is strengthened. The nature of

the soft and silky varieties equally correctly designates the use to which they should be put, which is to make warp yarns in which solidity and strength, rather than bulk, is required; and in wefts which are needed to be round, fine, and strong, for fabrics which are to be light and clear in texture, or very close and solid, such as are usually woven with wet weft.

In this stage, therefore, the number of times the material should be drawn and doubled depends mainly upon the class of cotton in use, and, secondly, upon the purpose for which it is intended. The object sought to be attained being to draw the fibres into parallel order, any manipulation beyond this is unnecessary, wasteful, and injurious—wasteful, because the time, power, and supervision employed is spent to no good result, and the cost of it lost; and injurious, because the fibre is damaged and injured for subsequent stages. Cotton which is drawn too much makes a weak yarn, as the fibres are strained until the natural convolutions shown in the illustrations of the magnified fibres are destroyed or injured to such an extent that they will slide over, instead of interlocking with each other, when the thread is subjected to a strain. For the soft kinds of cotton, when intended for numbers not exceeding 32^s, its passage through two heads of drawings of eight ends each, equal to sixty-four doublings, will often be found sufficient. If more be needed, three passages are given of $8 \times 6 \times 6 = 288$; if still more be required, eight ends are put up through each head, when the number of doublings stand thus, $8 \times 8 \times 8 = 512$. Sometimes, though but rarely, this number is exceeded. The number of doublings, however, always, to a more or less extent, depends upon the personal opinion of the spinner, which is often affected by incidents of individual experience.

An even temperature should if possible be preserved in the rooms containing the drawing machinery, and especially should extremes of dampness and dryness be avoided, as the former causes the rollers to “lick” the fibre around

them, making a great quantity of waste, and weakening the yarn through its loss, whilst excessive dryness of the atmosphere, as experienced in dry hot days in summer, or during the prevalence of dry east winds at other seasons, causes the fibre to curl and fly off, owing to the friction of the fibres over one another developing a perceptible amount of electricity. Drawing frames should, therefore, never be placed in damp rooms; and ground floors, unless well drained, and rendered quite dry, are unsuitable. The ventilation should be arranged so that currents of air shall not impinge upon the machinery, especially the working parts through which the cotton is passing.

SLUBBING.—This process is closely akin to the former. There is, however, no doubling in it. It consists of the drawing or attenuation of the sliver as delivered from the last frame into one of much smaller dimensions, called a slubbing. Instead of six or eight slivers, however, being combined into one as before, only one is put up, and which, passing through a series of three pairs of rollers, similar to those of the drawing frame, is attenuated in any required degree. Instead of being coiled in a can as in the drawing frame, by means of a flyer carried on a revolving spindle, it is wound upon a bobbin. This is the first machine of the series called bobbin-and-fly frames. The machines included under this name consist of the following: slubbing, intermediate, roving, throstle-spinning, and throstle-doubling frames, which are all identical in principle, though differing considerably in detail.

The slubbing frame is generally constructed with about sixty to eighty spindles, the latter usually being a maximum number. These are of a size to fit them for the reception of bobbins or tubes, ten to twelve inches in height. The winding-rail has a correspondingly extensive traverse. In this passage, the cotton is first twisted, the sliver having been attenuated to such an extent that its coherence without it would not, in the subsequent process, be sufficient to pull the bobbin round when being drawn off.

But as the strand of fibres has to be still further attenuated, and much twist would prevent this, no more is put in than is necessary to accomplish this purpose. As this and the two following machines are much alike, and constructed on the same principles, they may be grouped together when a description of one will serve for all.

INTERMEDIATE OR SECOND SLUBBING.—This is in all essential respects a repetition of the last process, though the machine contains rather more spindles, say from eighty to one hundred, the bobbins also being smaller, from eight to nine in. lift, and of a proportionate diameter. The intermediate frame is not often employed in the production of counts below 20^s, unless of a very good quality. As the slubbing from the preceding machine has been reduced or attenuated, as far as in this stage is desirable, two strands of slubbing are put up, and by a draught of two are united into one. This reduces any irregularity that yet remains to one-half of its former dimensions, in which state it may be regarded as practically reduced to nothing. There is, however, another risk introduced. The slubbing bobbins are placed in a creel at the back of the frame, and in number are double those of the spindles in the front. As two slubbing strands go to form the intermediate slubbing, it is obvious that, on the breakage or exhaustion of one, the other may continue working with the draught as before, and yield a slubbing only half as thick as required. In this condition it is called “single,” and whenever present to any considerable extent, constitutes a serious defect.

ROVING.—The roving frame is the succeeding frame to the intermediate slubbing, and the process itself is the terminal one of the preparatory stages previous to the final one of spinning. Here the strand of cotton is reduced to such proportions that, under ordinary circumstances, it can easily be draughted in the process of spinning to the required dimensions. In the case of spinning the finer counts, however, another frame is introduced,

called the jack frame, by which the roving is reduced considerably further to render the work of the mule easier in the final draught.

As before observed, the roving frame is one of the series of bobbin-and-fly frames, and the opportunity may be taken of describing it as the representative machine of the series. In its details it is smaller than either of the preceding machines. The sizes of the spindles and bobbins are decreased, whilst the number are increased, ranging from 100 to 140, the lift of the bobbin being reduced to from five to seven inches. Unlike the slubbing frame, which draws its supply of raw material from the sliver cans, it is fitted with a creel or frame, *a*, Fig. 41, for the reception of the bobbins from the slubbing or the intermediate frame, which ever may immediately precede it. These creels contain the tubes holding the attenuated sliver, now called slubbing. The tubes are arranged vertically, with two rows, *b b*, in a tier. They are retained in position by pegs, on which they revolve. These pegs were formerly made from lance-wood, but now are constructed of cheaper material, having hardwood tips inserted at the bottom. This lessens their cost, without diminishing their durability. On these pegs the bobbins easily revolve, the pull necessary to cause the delivery of the rove being so slight as not to strain it. In the slubbing frame there are four pairs of rollers, but in the intermediate and roving frames there are only three. These rollers extend across the frame from *c c'*. The bottom rollers are fluted, whilst the top ones are plain, and covered with leather. The top rollers are now generally made with loose bosses—an improvement due to the late Evan Leigh, and one which has proved of great value. The rollers are mounted on a beam, technically called the roller-beam, extending the length of the frame, and fixed between the creel and the spindles. Metallic plates, called caps, cover the rollers, and serve to protect them from dust, foreign substances, or accidental injury. The spindles are arranged in two rows, one behind the other, but alter-

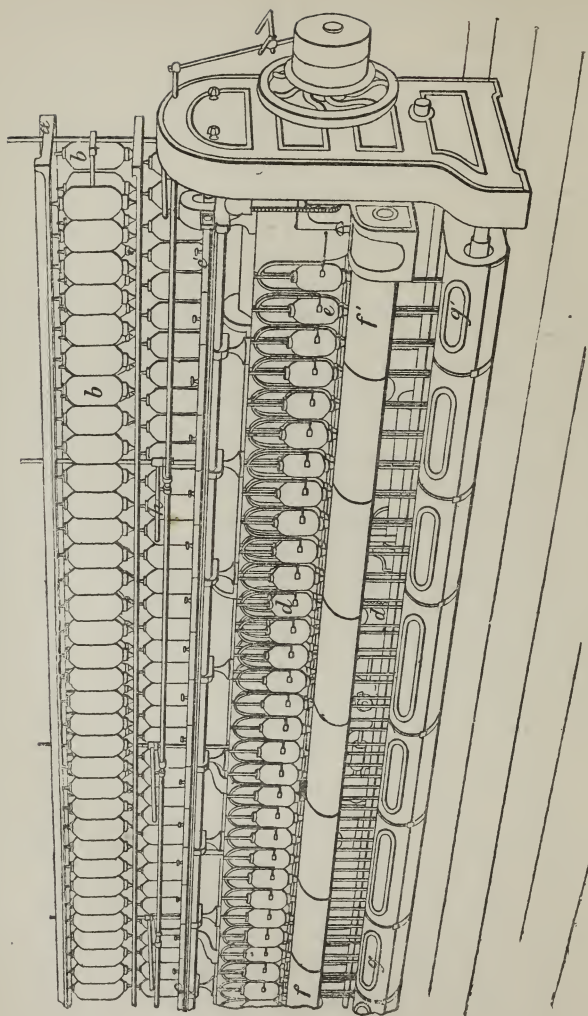


Fig. 41. Reving frame.


nating in position, as seen at *d*, in order to economize space. Each spindle is mounted with a flyer, fixed upon the top. The slubbing, intermediate, and roving frame-flyers are each furnished with a "presser," or pressure finger, *e*, which by its action compresses the material upon the bobbins or tubes upon which it is being wound, thereby enabling a much larger quantity to be put upon them than would otherwise be the case. Before the application of these, the bobbins were filled very quickly, and the operation of "doffing"—that is, removing the filled bobbins, and supplying the frame with empty ones—was necessary three or four times where once is now quite sufficient. Whilst this was being performed the machine of necessity was stopped, and much valuable time lost. This loss is now reduced fully 75 per cent., the time gained being economized for productive purposes. A corresponding advantage also results in the spinning department from the same change, the bobbins lasting four times as long as previously before becoming exhausted, thus economizing labour, increasing the production, and improving the quality. Formerly the bobbins had large flanged heads, in order to retain the slubbing or rove upon the barrel; but these are now dispensed with, the material as it is wound upon the tubes now being coned at both extremities. By these improvements the economy effected in the wear and tear of bobbins has been very large. The arms of the flyer—to one of which the presser is fitted—are tubular; and the presser is interchangeable, being made to fit both legs. As the spindles revolve at a high speed, it will be obvious that, to prevent injurious oscillation and great wear and tear of the spindles and bolsters, the flyer should be nicely adjusted, and perfectly balanced in its position, otherwise numerous evils will result. Two horizontal shafts extend throughout the length of the machine, under each of the series of plates marked *ff'* and *gg'*. The lower pair carry the bevel wheels that gear into smaller ones upon the spindles by which the latter are driven.

Similar gearing upon the upper shaft drives the bobbin, in connection with a differential motion, at a slower or quicker speed, as may be arranged, accordingly as the bobbin may be desired to lead or follow the spindle in the rate of its revolution. It has until recently been generally thought desirable that the bobbin should follow and not lead or run in advance of the flyer. Latterly, however, opinion on this point has undergone a considerable change, and corresponding alterations have taken place. The cause of this is chiefly the fact that the spindles always commence their movement before the bobbin, because of their connection with the first motion or driving shaft of the machine being positive by means of gearing; whilst the bobbins are driven through a differential arrangement which includes the cone pulleys and their connecting strap, and which therefore do not start so promptly. Owing to this fact, when the flyer leads, a slight stretching of the rove takes place, which injures it. When the bobbin is arranged to lead, this is avoided, as the roving is momentarily slackened, though this is immediately taken up when the different parts have got properly at work.

The proper driving of the spindles and bobbins of a fly frame, especially in the slubbing, intermediate and roving frames in which the driving is required to be positive, involves one of the nicest problems in mechanics. The strand of cotton is attenuated in the slubbing frame to such an extent as to require a slight amount of twist to secure its cohesion. In the intermediate frame the same thing takes place, and is again repeated in the roving frame. But the total amount of twist put into the rove, after its passage through the three machines, is only very small, not often exceeding two or three turns per inch. The exact "twist" depends upon the quality of the material in use. The attenuation of the sliver may have been carried from half-hank to four, five, or six-hank in the roving. It will be obvious that when the strand of cotton has been attenuated to this degree, and not having received more

than two or three turns of twist per inch, its cohesive power is of the smallest degree, and that the most perfect adjustment of the winding process to the delivery of rove by the front rollers is necessary in order to prevent strain or breakage. The rate of delivery by these rollers is constant; and the revolution of the spindles in putting in a given quantity of twist requires to be constant also. Were the rove, after being twisted by the spindles, delivered into a fixed receptacle, or, say, a sliver can, there would be no difficulty in the matter. But as for facility of handling in subsequent processes, preservation from injury, and the prevention of waste, it is necessary to wind it upon tubes or bobbins, this introduces the complications that constitute the problem referred to above. At the first glance, this winding would appear to be equally easy of accomplishment with the preceding, merely requiring a proportionate rate of revolution of the bobbin. But the difficulty lies in the proportionate rate being a variable, instead of a fixed one, for the diameter of the surface upon which the rove is wound increases with every layer wound upon it. This rate of increase is a calculable one, and it requires a proportionate acceleration of the speed of the bobbin when, as we assume, the latter follows the flyer. The solution of this problem quite baffled the skill and ingenuity of Arkwright, and was not satisfactorily solved until the invention of the well-known differential arrangement of Holdsworth, the principle at least of which is now universally in use to-day. The winding commences with the bobbin at a minimum of speed, the acceleration taking place on the completion of each layer, and, therefore, with each change of movement of the traverse rail, whether commencing at the bottom or top. It attains its maximum rate with the winding-on of the last layer, when the bobbin is filled. The speed of the bobbin is, however, a constant quality during the winding-on of each layer. When however the newer arrangement referred to above is adopted, and the bobbin arranged to precede the flyer, the former com-

mences the winding process at its maximum rate of revolution, the changes that take place being a succession of alterations each of which retards its speed.

The principle of increasing the speed of the bobbin just outlined, and which is technically known as the "differential motion," is often a puzzle to students commencing the study of cotton spinning and the cognate industries. It will, therefore, be advisable to dwell somewhat longer on the subject, in order to more fully elucidate it. Suppose the front rollers of a roving frame deliver 600 inches per minute of rove, which has to receive three turns of twist per inch, the spindles will require to make 1,800 revolutions per minute, to put into the rove the amount of twist desired. It will be obvious that the rove when twisted must be got out of the way, which is accomplished by winding it upon the bobbin. To illustrate this, let us suppose two points separated from each other, yet connected by a line, A  B, the first, A, indicating the bobbin, and the second, B, the spindle. It is essential to maintain the connection, represented by the line, between them. If it be necessary for B to move forward 1,800 inches in the direction of the arrow, the line being inelastic, and breakage not permissible, A must follow an equal distance, the result being that the relationship between the two points is unchanged. But if the line can be extended, or, to use a nautical phrase, payed out by B to the extent of 600 inches during its movement of 1,800 inches, it will only be necessary for A to follow a distance of 1,200 inches in order to maintain the link. This will show the intimate connection that subsists between the bobbin and flyer, which is not affected by the fact that their movements are circular, instead of, as here supposed, horizontal. But this by no means exhausts the phenomena: a step further must now be taken.

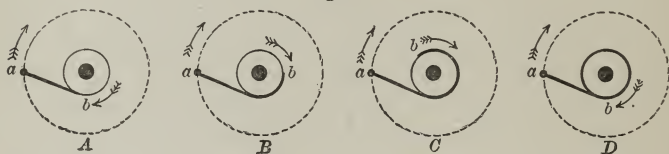
Instead of placing the two points as before, and giving them movement in a horizontal direction, let them be put in the position which will more nearly represent the facts

of the case. The following figures represent plan views of the spindle, bobbin, flyer, and rove in different positions. In each diagram let the central point represent the spindle, the small circle the bobbin, A, and the outer ring the circle described by the point, B, which will stand for the foot of the flyer, whilst the line, c, connecting the bobbin with the flyer, will represent the rove. As in the supposition above, if the foot of the flyer, B, makes 1,800 revolutions whilst connected by c with A, the latter must make the same number of revolutions to prevent the line, c, being either broken or strained. Revolving in concentric circles around a common axis, the greater distances travelled by the point, B, and the point of the bobbin, A, to which the line, c, is attached, will not affect their relationship. But taking the second part of the above supposition, allowing B to pay out to A 600 inches of rove during the time it is making 1,800 revolutions, it will be obvious that the bobbin, A, can have its speed reduced, and indeed must have it reduced, in order to prevent entanglement of the rove, to such an extent as to allow B to wrap or wind the 600 inches of rove around it. The illustration up to this point shows that the winding of the rove upon the bobbin or tube is accomplished by the greater speed of the revolution of the flyer over that of the bobbin, and that the amount of winding will always be represented by the difference between their rates of revolution.

The illustrations, Figs. 42, 43, will make these points quite clear. Let the diagram A, Fig. 42, represent the position of bobbin and flyer at the time of starting, *a* being the flyer, and *b* the point of the bobbin to which the rove is attached. In the second diagram, B, it will be seen that the flyer, *a*, has made one revolution, and has returned to its former position. In order to simplify the illustration, let us assume that the proportionate rates of revolution of the flyer and bobbin are as three to two. It will thus be seen that whilst the flyer has performed one complete circuit, the bobbin has only made two-thirds of a revolution,

which has allowed the flyer to wind the rove round one-third of its circumference. Thus, if the bobbin be 3 inches in circumference, it will have traversed 2 inches, while the flyer has made a complete revolution, and has given out 1 inch of rove which has thus been wound upon the bobbin. The diagram c shows that the flyer has completed a second revolution, the bobbin having fallen another one-third of a revolution behind, and a second inch of rove having been wound upon it. The next, d, illustrates the

Fig. 42.



Diagrams explanatory of winding process.

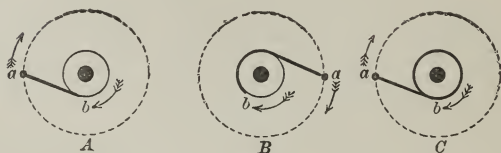


Fig. 43.

completion of the third revolution of the flyer, and the second of the bobbin, whilst the third inch of rove has been added upon the latter, thereby completing the first round of 3 inches.

In each of the foregoing diagrams the flyer is shown after each revolution as having returned to the point from which it started. In Fig. 43 the bobbin is dealt with in the same manner, which enables the advance of the flyer to be more clearly shown. In the first, A, the positions

are as shown in the preceding diagram at starting, whilst in B the bobbin has completed one revolution = $1\frac{1}{2}$ flyer, therefore the flyer is half a revolution in advance of the bobbin, the rove wound up being = half the circumference of the bobbin, or $1\frac{1}{2}$ inch. In diagram C the bobbin has returned a second time to the point whence it started, whilst the flyer has completed three revolutions, and has given out 3 inches of rove, which it has wound around the bobbin, completing its encirclement for the first time. This process is repeated until the whole length of the bobbin intended for the reception of rove is covered by a first layer, the winding of one fold upon another being prevented by the gradual elevation of the bobbin upon the spindle between the legs of the flyer, which brings an uncovered portion of the barrel opposite the eye of the flyer. Throughout this traverse the speeds of the flyer and the bobbin in their relation to one another have been uniform and unchanged.

By the deposit upon the tube or bobbin of the first layer of rove, the surface upon which the winding must now take place has been enlarged. As the diameter of the tube was one inch, it is now one inch plus the diameter of the two plies of rove which a line drawn through the middle of the tube from one outside of the layer of rove to its opposite, would bisect. It is usual to find the diameter of one ply of rove by carefully measuring the diameter of a full bobbin, subtracting that of the empty one from it, and dividing the difference by the number of layers upon it, which gives the diameter of two plies, there being, as we have seen, two plies in the diameter of each circuit; this divided by two, gives the diameter of each ply. Let us assume that the diameter of the bobbin when empty is 1 inch, and when full 3 inches, the difference will be 2 inches. Suppose the full bobbin to contain twenty-four layers of rove, this number must be used as a divisor of the 2 inches, when the position may be stated thus:—

$2 \div 24 = .0833 \div 2 = .04166$, the diameter of one ply of rove. As the bobbin or tube, to begin with, is 1 inch in diameter, the first layer will add .0833, the diameter of two plies of the rove, making the result, $1 + .0833 = 1.0833$, the new diameter. The circumference of any circle being 3.1415 times its diameter, the former can always readily be found by using this figure as a multiplier. Every successive layer of rove, therefore, will increase the diameter by the diameter of two plies of the rove, the same as before, and each new diameter multiplied by 3.1415 will give the new winding surface of the bobbin in process of being filled. Paying regard to this principle, we shall find the following to be the result in the case under supposition:—

1 in. diameter of bobbin.

1st layer	1	+	.0833	=	1.0833.
2nd	„	1.0833	+	.0833	= 1.1666.
3rd	„	1.1666	+	.0833	= 1.2499.
4th	„	1.2499	+	.0833	= 1.3332.
5th	„	1.3332	+	.0833	= 1.4165.
10th	„	1.7497	+	.0833	= 1.8330.
15th	„	2.1662	+	.0833	= 2.2495.
20th	„	2.5827	+	.0833	= 2.6660.
25th	„	2.9992	+	.0833	= 3.0825.

The rove is delivered from the flyer in a cylindrical form, but, when wound upon the bobbin, contact with the barrel and compression by the presser transforms it into an ellipse; the same change also occurs in the rove of each successive layer. This, however, does not affect the calculation when the diameter is obtained as above, because it is taken after the rove has been thus compressed.

The rove is wound helically upon the tube by means of an arrangement called the traverse, which consists in making the bolster rail move upward and downward, sliding the bobbin up and down the spindle at such a rate as to allow the coils of the rove to be laid contiguously to

each other upon the barrel. When the traverse is completed, the movement of the rail is reversed, and at the same moment the speed of the bobbin is accelerated, and a second layer is laid upon the first; the bobbin, if before ascending, now descending, or contrariwise. After the second layer is completed the bobbin again turns back, receiving at the same instant a further acceleration of speed. This takes place at the completion of every layer.

With the increasing diameter of the bobbin a fewer number of turns are required to take up the rove delivered. This enables the lift or traverse to be diminished by about the amount of one coil per traverse, and as this diminution takes place at both ends, the effect is that the rove at the extremities of the bobbin is built upon it in the form of cones, the lower one of which is inverted, as will be seen from Fig. 44, in which two bobbins are shown upon the spindles, one being empty, and the other full. It may be necessary to observe that the arrangement here described of the differential motion, and its application to both the speed of the bobbin and the lifting of the traverse rail, necessitates the uniform filling of one "side" of bobbins at a time, and a similar order of doffing; not permitting, as in the flyer spinning frame, the doffing of one bobbin at a time if it is thought desirable.

The spindles of the slubbing, the intermediate, and the roving frame are constructed alike, and with only slight variations in detail by the different makers. The following Fig. 44, exhibits a detailed view. The spindles, $x x$, are mounted in the frame as shown, one behind the other, and are driven by the shafts, $B B'$, by means of the bevelled gearing, $a^4 a^5$. The flyers, x^1 , are securely mounted upon the spindle tops at x^2 so as to partake of their rotatory motion. The flyer consists of a tube, x^2 , and two hollow legs, $x^3 x^4$, to which the pressure fingers, $z z$, are affixed at z^2 . The latter turn freely on their bearings at z^2 , the pressure upon the bobbin being induced by the quick rotation of the spindle and the resistance of the air against

the bobbin. The slubbing, after being delivered by the rollers, is conducted into the tube of the flyer at x^2 , and comes out of it at o ; it then enters one of the tubular legs at z^1 , from which it emerges at z^2 , when it is coiled several times round the presser, z , which assists to consolidate it, and then passes through the hole, z^3 , upon the

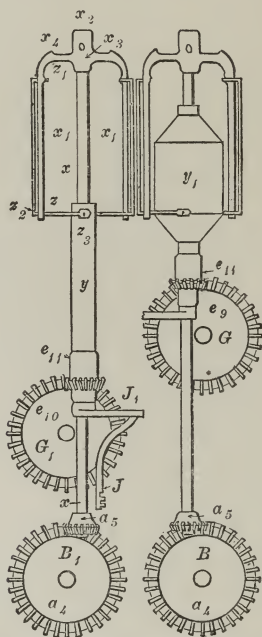


Fig. 44. Slubbing Frame. Spindle gearing and bobbin traverse.

bobbin, y . The bobbins receive their motion from similar shafts, G G' , and gearing, e^{10} e^{11} , to those of the spindles. As the two shafts driving the spindles of the front and back row are actuated by a common driver, they necessarily revolve in opposite directions; in order, therefore, to secure the revolution of both lines of spindles in one way, one row is placed to the left and the other to the right of the driving

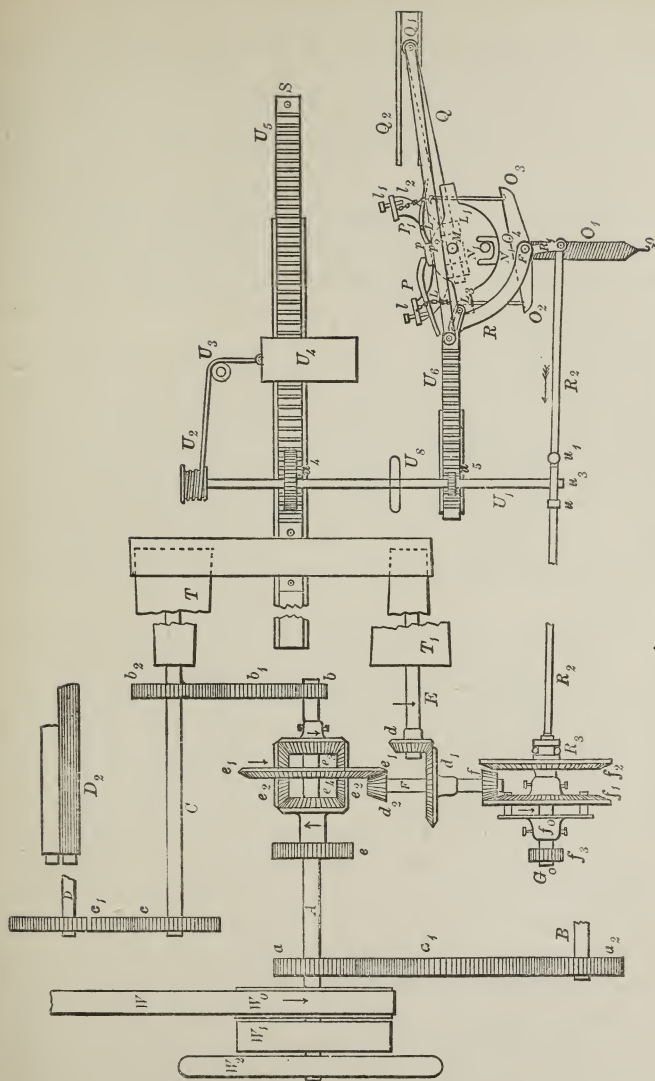


Fig. 45. Roving Frame. Differential driving arrangements.

shafts. A similar arrangement prevails with regard to the driving of the bobbins, as will be seen from Fig. 44.

These complex yet harmonious movements are produced by some very ingenious mechanical arrangements which now require description. The following illustrations, representing the mechanism of a roving frame in the order of its parts, will be of assistance to a thorough comprehension of its structure and working. Being different presentations of the same mechanism, the respective parts, as they appear in each drawing, are marked with the same reference letters.

The driving shaft, A, Figs. 45 and 46, is usually fitted with 12 in. fast and loose pulleys. A wheel, *a*, upon this shaft works into a carrier wheel, *a* 1, which actuates another wheel, *a* 2, upon, and by which, the spindle shaft, B, is driven. This wheel gears into a similar wheel, *a* 3, upon the spindle shaft, B 1, which being of the same size, both shafts revolve at the same speed. These shafts, B, B 1, carry the bevel gearing driving the spindles, and which has been previously described.

The shaft, A, first mentioned, also carries a pinion, *b*, Fig. 45, working into a carrier wheel, *b* 1, which again actuates another wheel, *b* 2, on the shaft, C, of the driving cone. Upon the latter shaft there is a wheel, *c*, gearing into a second, *c* 1, actuating the front roller shaft, D. A pinion, *c* 2, Fig. 47, upon this shaft drives a wheel, *c* 3, on the axis of which is a pinion, *c* 4, gearing into another wheel, *c* 5, which drives the back roller, D 2. Upon the back roller is a pinion, *c* 6, actuating a carrier wheel, *c* 7, driving a pinion, *c* 8, upon the centre roller, D 1.

As remarked before, the arrangement of the rollers is such that only a very small draught occurs between the back and middle roller, nearly the whole of the latter occurring between the middle and the front rollers. The rollers are usually set by means of a gauge, the distance from centre to centre of the front and back roller being such as not to exceed, or fall short of the length of staple

of the cotton in use. The three bottom rollers are fluted, and also the top back roller, but the middle and front top rollers are covered with leather. The top rollers rest upon the bottom ones, and are moved by contact with the latter. This is preserved by means of weights suspended on hooks.

The differential driving of the bobbins yet remains to be explained. The shaft, *A*, besides the wheel, *a*, driving the spindles through the train of gearing as described, carries

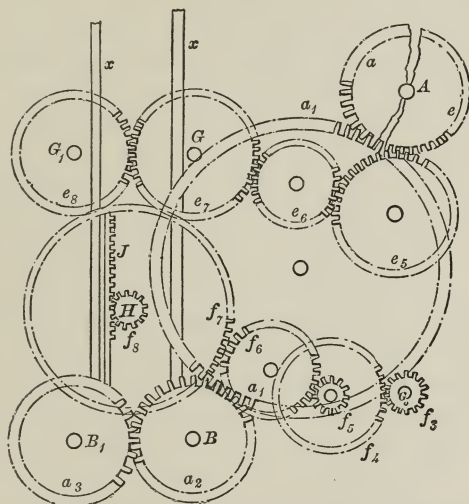


Fig. 46. Roving Frame. Differential driving gearing.

a second wheel, *e*, which is shown broken upon the shaft, *A*, in Fig. 45, and more distinctly, but without its connected train, in Fig. 46. The bobbins receive their motion from this wheel, the revolutions of which are required to increase by a constant number, as each added layer of rove enlarges the diameter of the bobbin. This acceleration of the revolution of this wheel is produced by a cone driving-motion connected with a differential wheel-motion, commonly called a "jack in the box" motion. The cone, *T 1*, is driven by a

strap from the cone, T. In form, the latter is slightly concave, and the former slightly convex. These cones require to be made with great accuracy, so that the revolutions of the shaft, E, which is driven by the cone, F, shall increase in exact proportion, according to the space the strap is traversed towards the largest diameter of the cone, T. The shaft, E, at its extremity carries a bevelled pinion, *d*, gearing into a wheel, *d* 1, of the same description upon the vertical shaft, F. On the top of the shaft, F, there is a bevelled pinion, *d* 2, working into the wheel, *e* 1. The differential mechanism is constructed as follows: the wheel, *e* 3, is fixed upon the shaft, A; the upper and the lower wheels, marked *e* 2, gearing with *e* 3 on one side, and *e* 4 on the other, have their bearings in the body of the wheel, *e* 1. The wheel, *e* 4, is cast in one piece with the wheel, *e*, and both this double wheel, *e*, *e* 4, and *e* 1, are loose on the shaft, A. It will be obvious from the arrangement shown in the figure that the wheels, *e* 2, are of necessity alike, as are also *e* 3 and *e* 4. If the wheel, *e* 1, is kept stationary, and *e* 3 is turned round once in the direction of the arrow, the wheel, *e* 4, will also be turned once round through the wheels, *e* 2, gearing simultaneously with the wheels, *e* 3 and *e* 4. The movement of this wheel, however, will be in the contrary direction to that of *e* 3. By this action the wheel, *e*, is made to revolve at the same rate as the shaft, A, though the direction of its revolution is reversed. If, on the contrary, the wheel, *e* 3, is drawn back, and if the two wheels, *e* 2, are fixed in their places so that they cannot move, then, on turning the wheel, *e* 1, once round in the direction of the arrow, the wheel, *e* 4, will also be turned once round the teeth of one of the wheels, *e* 2, just engaged with *e* 4, acting as a driver and turning the latter in the same direction as *e* 1. If the wheel, *e* 3, be brought in gear again, and kept stationary, but the wheels, *e* 2, be permitted to revolve freely round their axles, then for one revolution of the wheel, *e* 1, in the direction of the arrow, the wheels, *e* 2, will roll once round *e* 3, and, as this is kept stationary, the

wheels, e_2 , turn round upon their axles, turning the wheel, e_4 . One revolution of the wheel, e_1 , causes two revolutions of the wheel, e_4 , in a direction opposite to that caused by turning the wheel, e_3 . This shows the principle of its action, from which it will appear that when in work the actual number of revolutions of the wheel, e_4 , are equal to the number of revolutions of the wheel, e_3 , less the double number of revolutions of e_1 .

The wheel, e , drives by two carrier wheels, e_5 and e_6 ,

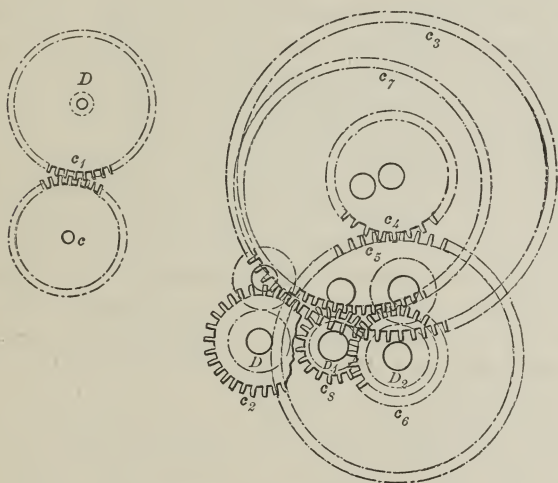


Fig. 47. Driving Gearing.

Fig. 46, the wheel, e_7 , upon the shaft, G , and e_7 gearing into e_8 , actuates the shaft, G_1 , driving the second line of bobbins. As e_7 and e_8 have the same number of teeth as e , the revolutions of the two shafts, G , G_1 , are equal to the revolutions of the wheel, e . The bobbins are driven by the wheels, e_9 , e_{10} , geared into e_{11} , as previously described. On the boss of the wheel, e_{11} , there are slight projections that fit into grooves cut in the bottom of the bobbin, by which arrangement the bobbins are carried

round. They are required to fit loosely upon the spindle to permit of doffing with facility.

The vertical traverse of the bobbin, as well as the acceleration of its speed, is obtained from the cone motion. The vertical shaft, *F*, Fig. 45, near its bottom carries a pinion, *f*, gearing into the bevel wheel, *f* 1, on the shaft, *G* 0, Figs. 45, 46, which carries the pinion, *f* 3, working into *f* 4, Fig. 46, on the axle of which is the pinion, *f* 5, driving by a carrier wheel, *f* 6, the wheel, *f* 7, upon the shaft, *H*, which it turns. On this shaft, *H*, are a number of pinions working into racks having a proportionate number of teeth. The latter, *J*, are fixed to the bobbin carriage, *I*, Fig. 44, which moves up and down on slides. The shafts, *G* and *G* 1, Fig. 46, are contained in this carriage, and necessarily also the bevel gearing upon them working into the pinions, *e* 11, by which the bobbins are driven. It will now be obvious that the shafts, *G*, *G* 1, and the gearing and the bobbins, ascend and descend with the traverse of the carriage. Winding is commenced with the strap on the extremity of the cones, which gives the longest vertical traverse to the carriage, and the lowest rate of revolution to the bobbin. The extreme position on the opposite side, shown in Fig. 45, gives the maximum rate of revolution to the bobbin, and the shortest traverse to the carriage.

On the shaft, *G*, Fig. 45, there is a second wheel, *f* 2, exactly like *f* 1. This shaft has a vertical motion of small extent, the effect of which is to alternately engage the wheels, *f* 1, *f* 2, with the pinion, *f*, which reverses the direction of revolution of the shaft, *H*, Fig. 46; thus, when the pinion is working into *f* 1, the bobbins descend, on the completion of which movement the pinion, *f*, begins to work into *f* 2, when the revolution of the shaft is reversed and they begin their ascent. It will be plain that a difficulty would be experienced in adapting geared wheels to work together when the distances of their axis from each other is continually changing. This has been overcome in this case by placing the bearings of the two wheels, *e* 5, *e* 6, in

two links, oscillating on the two shafts, A and G, in such a manner that when the shaft, G, is at half of its ascent, the axis of $e5$ lies vertically under the shaft, A, and when at the bottom this axis again assumes the position shown in Fig. 46. The axis of $e5$ oscillates upon A, having its distance from G maintained uniform.

The reversing of the carriage traverse and the changes which that implies are accomplished by the arrangements now to be described :—M, Figs. 45 and 48, is a fixed pin on

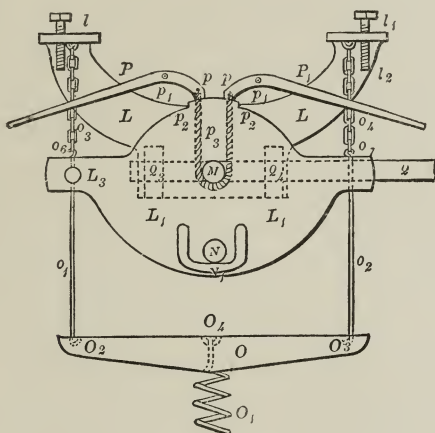


Fig. 48. Traverse reversing arrangement.

which the pieces, LL and $L1L1$, turn freely, the latter carrying a pin, N , the range of its oscillation being limited by the fork, $N1$. The piece, $L1$, has on the top a round projection forming two lugs, $p2p2$. The levers, p and $p1$, oscillate upon fixed points, $p1p1$, whilst their ends, pp , corresponding with $p2p2$, are connected by a spiral spring, $p3$, which presses them against $L1$.

The beam, o , is suspended by the rods, $o1$, $o2$, both of which pass through $L3$, and terminate in hooks, $o6$, $o7$, which obstruct any downward movement of the rods.

These hooks are attached to the chains, *o 3, o 4*, which themselves are fastened, at *l, l 1*, to the piece, *L*.

Let the piece, *L*, be turned to the right, round *M*, and *l* will rise, whilst *l 1* will be depressed; *o 2* will be elevated, and *o 3* lowered. This will cause the rod, *o 2*, to be pulled, and as the hook, *o 7*, lies against *L 1*, the latter will also be turned to the right. The pin, *N*, is thus brought against the left side of the fork, *N 1*, and *N* is prevented from turning any further in the same direction, so that should the point, *o 2*, be raised further, that of *o 3* will remain unmoved. This further lift takes place, the consequence being that the beam, *o*, turns upon *o 3*, lifting *o 4*, and bringing an increase of tension upon the spiral spring, *o 1*; *o 2* approaches *L 1*, and the point, *L 3*, because the latter does not change its position, *o 6* as a consequence being lifted off *L 1*. Let the fork, *N 1*, now be removed, and the beam, *o*, and the spring, *o 1*, will return to their former position of equilibrium, the point, *o 4*, again becoming the fulcrum of the beam, *o*. The point, *o 2*, however, cannot fall, consequently *o 3* and *o 4* are lowered, *o 2* becoming the fulcrum of the movement. As the point, *o 3*, falls, the hook, *o 7*, turns the piece, *L 1*, round upon the pin, *M*, so that the point, *L 3*, makes an upward movement. By the sudden contraction of the spring, the last-named point is also led to make a sudden movement in an almost vertical direction.

The turning of the piece, *L*, is effected by the following means:—*q 2*, Fig. 45, is a pair of horizontal slides fixed to the frame of the carriage, and sharing in its vertical movement. As shown in Fig. 45, it is in the highest position, as at the moment when the downward movement of the carriage begins. These slide bars are adjustable, and must be so set that in the position given here, the vertical distance of the centre line from the point, *M*, must be equal to half the lift of the carriage, or after making half of its downward traverse, their centre line must lie in the same horizontal plane with *M*. Its extreme position is

therefore determined by the length of the bobbin to be covered. *Q* is a bar put through two lugs on *L*, and resting with a pin, *Q* 1, between the slide bars. If *Q* 2 is lowered, the piece, *L*, is turned round *M*, by *Q*.

In the position of *Q* 2, in Fig. 45, the end, *p*, of the lever, *P* 1, is in contact with the corner, *p* 2, and *N* is in contact with the right side of the fork, *N* 1. The point, *O* 3, is in its highest position, *O* 2 a little above its lowest, consequently *O* 4 is also lifted a little, and there is a slight amount of tension placed upon the spring, *O* 1. If, now, the downward motion of *Q* 2, and the turning of *L* round *M* begins, the hook, *O* 7, is first brought to bear against *L* 1, while the chain, *O* 3, is straightened. By this *O* 3 is enabled to sink *O* 2 without changing its position; *O* 4 is lowered, and the tension of the spring ceases in consequence of the movement of *O* round *O* 2. As the turning of *L* continues, the rod, *O* 1, and chain, *O* 3, are pulled, whereby the hook, *O* 6, is lifted off *L* 1; the point, *O* 3, cannot fall lower, therefore *O* turns round *O* 3 as fulcrum, and the spring is again loaded. This tension increases until the stud, *l* 2, presses upon the lever, *P* 1, and thereby disengages *p* and *p* 2. The spring now partially contracts *L* 1, turns suddenly round *M* till the pin, *N*, strikes against the left side of the fork, *N* 1, and the point, *L* 3, suddenly moves upward. At the same time the spring, *p* 3, forces the end of the lever, *P*, into the corner, *P* 2, and the pin, *N*, is thereby retained in this position. The upward traverse of the bobbin carriage now commences. In a manner similar to that just described, the point, *L* 3, suddenly moves downwards after the carriage has finished its upward traverse, and the operations re-commence.

In *L* 3 a pin is fixed sliding in a slot of the bell crank lever, *R* *R* 1, Fig. 45. This lever has its fulcrum in the pin, *r*, and therefore an upward movement of *L* 3 produces a movement of the rod, *R* 2, in the direction of the arrow. On the rod, *R* 2, there is firstly a fork, *R* 3, Fig. 45, clipping the boss of the wheel, *f* 2, which is shown more clearly in

Fig. 49, consequently a rapid motion of the rod, R_2 , in the direction of the arrow brings the wheels, f_2 , and f_1 , into gear. The wheels, f_2 and f_1 , being connected, f_1 is at the same time disengaged. Both wheels are loose on G_0 , but the sheave, f_0 , is fixed on it. This sheave reaches by means of two studs through the body of the wheel, f_1 , so that in this manner the motion of f_1 or f_2 is communicated to the shaft, G_0 . The direction in which the shaft, G_0 , and with it f_3 and f_8 , Fig. 46, revolve, is therefore alternating.

The rod, R_2 , carries a boss, U , Fig. 50, upon which are two catches, u and u_1 , kept together by the spring, u_2 . During the downward movement of the bobbin, the catch,

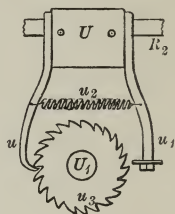
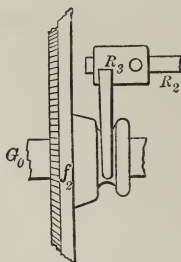


Fig. 49. Traverse reversing gear. Fig. 50. Cone strap ratchet.

u , is in gear with the ratchet wheel, u_3 ; by the movement of the rod, R_2 , reversing the traverse to the upward direction, the catch, u , is disengaged, and u_1 brought into gear. On the shaft, U_1 , Fig. 45, which carries this ratchet wheel is fixed a drum, U_2 , on which a cord is wound which passes over a grooved pulley, U_3 , and has a weight, U_4 , attached to its extremity. When the catch, u , is disengaged by the movement of the rod, R_2 , the shaft, U_1 , is caused to revolve by the action of the weight, and continues its movement until arrested by u_1 . The catches are so arranged that the wheel, u_3 , is turned half a tooth at each movement of the rod, R_2 , and as it has twenty-three teeth, the shaft, U_1 , is turned once round for every

forty-six reversions of the rod, R 2. The shaft, U 1, also carries the wheel, u 4, working into the rack, U 5, which is connected with the strap guide for the two cones. This rack contains forty-eight teeth for each $12\frac{3}{8}$ inches of its length, so that after forty-six reversions the strap will be found to have moved along the cones $12\frac{3}{8}$ inches, or for each reversion, $\frac{12 \cdot 375}{46} = 0.269$. The cone having a length of 30 inches, $\frac{30}{0.269} = 111$ reversions will take place, representing 111 layers of rove wound on when the strap has finished its traverse upon the cones from one end to the other. The shaft, U 1, carries another wheel, u 5, with sixteen teeth working the rack, U 6, which has sixteen teeth in $3\frac{5}{8}$ inches, and therefore moves during forty-six reversions of the shaft, R 2, $3\frac{5}{8}$ inches, or for 111 layers a length of $\frac{111 \times 3.625}{46} = 8.747$, or for one reversion $\frac{8.747}{46} = 0.1899$ inches. Connected with this rack is the sliding pin, Q 1, to which the rod, Q, is attached. The distance of Q 1 from M, or the effective length of the rod, Q, is altered by the rack. If the length of the vertical movement of Q 2 remained the same, shortening the rod, Q, would cause the oscillation of the piece, L, round M, to increase. But as the levers, P P 1, do not alter their position, this quicker oscillation of the piece, L, causes the reversion to take place sooner, and the length of the vertical movement of Q 2 is reduced in the same proportion as the length of Q diminishes. Thus it is that the rove is wound upon the barrel in the form shown in Fig. 44 making conical ends.

The self-acting stopping arrangement may be briefly described at this point. Fig. 51 shows the details of its arrangement. The rod, s 4, is connected to the strap guide for the driving pulleys. The bell crank lever, s 3, s 1, is fixed upon this rod and oscillates upon the pin, U 3, of the pulley for the weight, U 4. This lever has a projection, s 2, at the end of the part, s 1. A rod, s, is connected to the point, L 3, in such a manner as to share its movements, s 5 being a spring whose function is to prevent the rod, s, striking against the projection, s 2. The

rack, U_5 , carries a pin, s , which when the strap has passed to the end of the driving cone, presses the rod, s , against the spring, s_5 , and overcomes its resistance. When in this position, if the rod, s , is moved upward, it comes against the projection, s_2 , elevating the lever, s_1 , causing the arm, s_3 , to move the rod, s_4 , in the direction of the arrow, by which the strap, w , is moved from the fast to the loose pulley, and stopping the machine.

In order to secure an even distribution of the wear upon

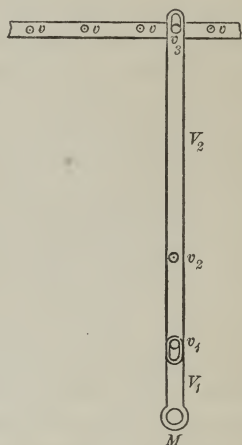
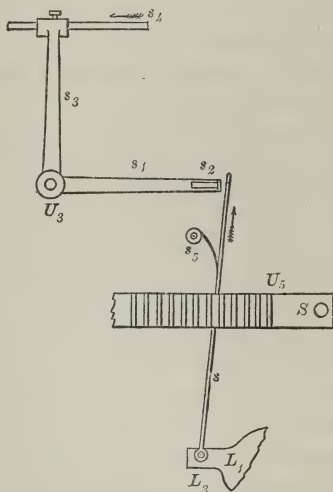


Fig. 51. Self-acting stopping motion. Fig. 52. Slubbing traverse motion.

the rollers, a lateral traverse is imparted to the slubbing when it enters the back rollers. Fig. 52 shows the means by which this is accomplished. A bar, v , contains holes, vv , each of which receives two threads from an equal number of slubbing bobbins, on their passage to the back rollers, determining the place at which they enter the rollers. This bar is guided horizontally by the lever, v_1 , which has its fulcrum at M , and is connected with L , sharing in the oscillation of the latter. Near the fulcrum, M , is a stud,

v 1, whilst a similar stud, *v* 3, is fixed in the bar, *v*. Both of these studs slide in short slots of the lever, *v* 2, whilst the latter swivels on the pin, *v* 2. Through this connection the bar, *v*, is made to share the lateral movement of *v* 1, multiplied by the ratio of its leverage, moving horizontally through being guided. By this means the slubbing is moved to and fro between the rollers, by which the wear is evenly distributed over a considerable portion of their surface, thus insuring their greater durability.

The process of doffing, or removing the bobbins when full, is performed by turning the spindles backward by means of the wheel, *w* 2, on the driving shaft. The bearing for the top of the driving cone is next lifted by a lever which causes the strap to become slack. The shaft, *u* 1, is then turned backward by the wheel, *u* 8, which action winds up the weight, *u* 4; the cone strap being by this means returned to the base of the driving cone, and *q* 1 brought back into its first position as shown in Fig. 1. The spindles are again filled with empty bobbins, when the machine is ready to re-commence operations.

To make the roving finer or coarser, the draught of the rollers has to be altered, which is effected by changing the wheels, *c* 2, and *c* 4, Fig. 47. In proportion as the number of teeth in these wheels are increased, the amount of slubbing taken in will be greater, and the rove coarser in the hank. With a diminution the opposite effect will result. With lower counts, the diameter of the rove being increased, a fewer number of coils are required to form a layer; this necessitates an increase of the speed of the vertical traverse of the bobbin carriage, which is obtained by changing the pinion, *f* 5, Fig. 46, for one having more teeth. When a finer rove has to be made, the substitute must be one of fewer teeth. With the production of a coarser rove, the velocity of the revolution of the spindles, and consequently, of the bobbins, must be increased, because the diameter of the layer of rove then put upon the bobbin being greater, its winding surface is increased, and therefore

the rate at which it will take up the rove will be such as to break the latter were it not counteracted by an acceleration of the speed in like proportion. Changing the ratchet-wheel, *u* 3, for one having a fewer number of teeth, secures this result; correspondingly, a finer rove requires a diminished number of revolutions of spindle, and a ratchet wheel of more teeth.

Such are the details of the roving frame. The intermediate frame which precedes it in the order of arrangement differs from it only in having its parts larger and correspondingly stronger. This difference necessitates a slower speed of the various parts, the proportion being when no wheels have been changed as five in the intermediate frame is to seven in the roving frame in all the revolving parts. As the rove produced on the intermediate frame is much thicker than that from the former, to prevent too frequent doffing and the loss of time consequent upon it, the bobbins are made larger, which necessitates stronger spindles and slower speeds to prevent excessive vibration. The diameter of the bobbin is increased, so that the winding on proceeds at the same rate as in the roving frame.

The slubbing frame compares with the intermediate, as the latter with the roving frame, the parts being proportionately larger and stronger. The speeds also are correspondingly slower; where the driving shaft of the former makes 250 revolutions, that of the latter only makes 220, the speed of the spindles being diminished in the same proportion. Often, however, the dimensions are the same, the differences being in these cases one of speed. The dimensions of the bobbins then are the same, though the coarser slubbing requires a ratchet wheel of less teeth in order to secure a corresponding acceleration of the spindle.

The slubbing frame is fed from cans of sliver from the card, whilst the intermediate and the roving frame receive their supply of material from slubbing and intermediate frame bobbins respectively, which are contained in creels.

The foregoing illustrations of the roving frame we have

reproduced from a small work on "The mule spinning process, and the machinery employed in it," from which also the description has been condensed, the algebraical formula being omitted as unsuitable to a great extent for the present treatise.



CHAPTER VII.

DEVELOPMENT OF SPINNING.

Spinning: its antiquity; conjectural origin; the first spindle.—Definition of spinning.—The whorl; the distaff.—Spinning as described by ancient historians.—The hand wheel; its first appearance in Europe; in India.—The Jersey, or common hand wheel; its development from the spindle; the driving wheel, the wharve.—Similarity between the European wheel and the Indian wheel; European wheel used for wool and cotton; process of spinning upon it.—The flax wheel, or the Brunswick and Saxony wheels; the flyer.—The two-handed wheel; the traverse.—The connection between the old and the new systems of spinning.—Cotton: antiquity of its cultivation and manufacture.—India, the birthplace of the manufacture; its extensive manufacture in that country.—Sterility of Indian invention.—Kay's inventions a stimulus to further improvements.—Widespread influence of inventions in the cotton trade.

SPINNING is one of the most ancient arts, and in its beneficial influences, one of the most important. It is difficult to conceive what would now be the condition of mankind had this art not been invented. Nothing is known of its origin, for the earliest records in which it is mentioned, show it in the condition of advancement in which, after it became known, it remained, without further progress, for many centuries. Thus it may have had its birth centuries previously to its first mention in history. Only conjectures can be offered regarding its beginning, and these may be either far from or near to the facts. The same difficulty meets the investigator in connection with the material which formed the basis of the first experiments and earliest operations of the art. The writer, in another place, has ventured to suggest that the first spinner was a shepherd-boy, and the material used a few locks of wool. Reclining under the shade of a tree whilst his flock was

feeding around him, it might easily happen to a playful youth to have his attention attracted by a small portion of a cast fleece lying near, to which he would stretch forth his hand. Toying and amusing himself with this to relieve the tedium of the hours, it might quite as easily happen that he should twist its fibres together between his fingers, and surprised at the ease with which they combined, draw them from the mass ; this process, repeated so as to obtain a thread exceeding the length of the original fibres, would give the first woollen thread. Whether the importance of his discovery vaguely dawned upon the mind of this hypothetical shepherd-boy or not, cannot now be told ; neither can it be known whether he carried his spinning operations beyond the first stretch or not. But clearly a time would come when this would be done, and as a greater length of yarn was produced, to prevent its entanglement would involve winding it upon a twig. Here comes into view the beginning of the spindle ; as yet, however, not yet used for its present purpose, or even such a purpose divined. But this in due course would grow out of the former. In order to prevent the unwinding of the yarn from the twig, in the event, say, of its falling from the hands of the spinner, the thread would be secured in a cleft made for the purpose at one end of the twig. Now further suppose, for there is nothing else available, that the spinner, after laboriously twining a length of yarn, instead of winding it upon the twig as usual, rises to his or her feet and allows the latter to dangle from the hand suspended by the length of yarn just spun, a new phenomenon occurs. The twig begins to revolve, slowly at first, but with an increasing velocity, until suddenly, whilst the spinner is contemplating this vagary, the thread breaks, and the twig drops to the ground. The spinner then finds that all the twist has been taken out of the fibres. The rapidity with which the fibres would be untwisted compared with the time it had taken the operator to twist them, could hardly fail to be recognized. Slowly it would break

upon his or her understanding, that if this revolving twig could thus take twist out by a reversion of its movement, it could be made to put it in. The mental suggestion would be acted on, and the trial that would follow would succeed. It can easily be imagined how that spinner would exclaim "Eureka! Eureka!" that is, if Greek happened to be one of his accomplishments, which is not probable; there would remain, however, its equivalent in his mother-tongue. This would be the first spinning spindle: that is, if our conjecture has been fortunate enough to hit the mark. All steps between this rude discovery and the perfect form of the spinning machine with which the world is now acquainted, consist of a series of improvements upon the original form.

As will have already been gathered from the above, spinning is the art of twisting together a number of filaments or fibres upon their own axis in succession, and in such a manner that a thread or line of greater length than the single fibres of which it is composed is produced. Spinning is thus something more than twisting, which is the twining of two or more threads together to form one, the length of which, however, never exceeds that of its component parts.

The first improvement that experience would dictate, and that at a very early time, would be the addition of a whorl to the bottom of the spindle. This would be suggested by the fact that a loaded spindle containing a quantity of yarn would rotate more easily, steadily, and continue longer than an empty one, or one not containing much yarn. It would therefore be easy to secure the best action by weighting its extremity with a piece of clay, wood, stone, or metal. This developed into the fixed whorl in process of time, and after many centuries, became the basis of another great step in advance. Concurrently with the invention of the whorl would be that of the distaff: this was simply a short staff on one end of which the raw material was placed, whilst the other was held under the

arm. thus leaving the hands at liberty, one to draw the material, and the other to manage the spindle.

With the invention of the whorl, and the introduction of the distaff, the inventive faculty seemed to have reached the limit of its power, as no further improvement appears to have been made until the hand wheel was invented.

Herodotus, Ovid, and Catullus, classic historians, all refer to, and at more or less length describe, the process of



Fig. 53. Greek Women spinning.

spinning as existing in the times in which they wrote. The following is the substance of their descriptions:—

“The spindle was a stick, ten or twelve inches long, having at the top a slit or catch in which the thread was fixed, so that the weight of the spindle might continually carry down the thread as it was formed. Its lower extremity was inserted into a small wheel called the whorl (*vorticellum*), made of wood, stone, or metal, the use of

which was to keep the spindle more steady, and to promote its rotation ; for the spinner, who was commonly a female, every now and then twirled the spindle with her right hand, so as to twist the thread still more completely ; and whenever by its continual prolongation it let down the spindle to the ground, she took it out of the slit, wound it upon the spindle, and having replaced it in the slit, drew out and twisted another length.”¹ The preceding illustration, Fig. 53, which is a representation of ancient distaff



Fig. 54. Indian Girl spinning.

spinsters, admirably illustrates these remarks. Let the reader note the vertical position of the spindle when in operation.

At what time the hand spinning wheel, which is a great improvement upon the distaff and spindle, was invented, does not appear ; but from the absence of all reference to it in any records entitled to be regarded as ancient, it is fair to infer that it is comparatively a modern invention.

¹ Smith's "Dictionary of Greek and Roman Antiquities," art. "Fusum."

The probabilities are that it made its appearance in Europe towards the close of the fifteenth or early in the sixteenth century. The illustration, Fig. 54, which exhibits the rude wheel of the natives of India, may be the progenitor of the common wheel of Europe, as intercourse between



Fig. 55. Single thread spinning.

the East and the West began to increase considerably about the time of the appearance of the hand wheel in Europe. It is desirable to point out that this particular illustration, which has appeared in many works treating of this subject, is erroneous, probably owing to an

imperfect comprehension of the matter on the part of the first artist who sketched it, maybe from description, and whose error has been copied by those who have reproduced it. A thread never was and never could be spun by such an arrangement as figured here. The spindle ought to be placed with its axis parallel to the axis of the driving wheel, and not as here, at right angles. The correct arrangement of this part is shown in Fig. 55, representing the Jersey, or common spinning-wheel of Europe.

Whatever may have been the period at or the country in which the hand spinning wheel was invented, is not now of much moment to discover. The internal evidence of its parentage, however, showing it to be an outgrowth of the older spindle, is very strong. The spindle of the distaff spinner in coming to the ground, when a length of yarn had been spun, would often, after falling into a horizontal position, turn upon the whorl, thus showing a form of revolution in a strange position. Ultimately, after this had occurred, perhaps hundreds of thousands of times, it might suggest the thought to some operator that, by fixing the spindle in a horizontal position, and using the whorl as an arrangement of levers, a continuous revolution of the spindle could be maintained. How to apply the motive power would be the next question that would suggest itself. For a time, probably, the whorl would be beaten round by the hand. The invention of the driving wheel and the transmission therefrom of power by means of a band would next follow ; and the discovery of a method of securing an increase of velocity when a small wheel was driven from a large one, would, in that early time, be as great a feat as Arkwright's discovery, at a later date, of the system of drawing by rollers. It is thus probably that the whorl of the old spindle became the wharve or small grooved pulley of the new or horizontal spindle of the hand wheel. It is almost a pity that history has not preserved the name of this inventor.

The general similarity of the European hand wheel to

the primitive wheel of India will be obvious when comparison is made between the two illustrations, Figs. 54, 55, care being taken to allow for the error in the former, as previously pointed out. The wheel represented in Fig. 55 was used for spinning wool, and subsequently cotton, until the invention of Hargreaves superseded it. In the drawing the hand cards by which the wool and cotton was prepared, are shown at A. After the material had been carded, it was spun into a thick, soft rove, having very little twist in it, such as is seen at B. This rove was then further drawn, in the next process, to the requisite dimensions to form yarn, fully twisted and wound upon the spindle, which generally contained a spool or pirn bobbin. This wheel was an intermittent spinning wheel, spinning a "draw" or "stretch," so called, probably, from its being the length obtainable by the outstretching of the spinster's arm.

In 1533 the flax spinning wheel was invented, it is said by a citizen of Brunswick, and for its particular purpose was an improvement upon the preceding. It was worked by means of a treadle, by the foot of the spinster operating a crank turning the driving wheel. In a comparatively short time afterwards this was superseded by a still more perfect machine called the Saxony wheel, also for spinning flax. This wheel is remarkable as being the first in which the flyer was introduced, and a differential driving for the bobbin. Further, it was also a continuous spinning wheel as distinguished from the intermittent wheel just described. Owing to the nature of the fibres, the system of spinning by the distaff and spindle held its ground firmly against both forms of the spinning wheel in both the woollen and linen trades, until towards the latter half of the seventeenth century, when the superior merits of the wheels began to be generally acknowledged. The intermittent spinning wheel was taken for woollen and cotton, whilst the Saxony wheel was widely adopted for spinning flax. This wheel was extensively used for flax spinning in Scotland even up to 1830, if not later. About the time that

Hargreaves invented his jenny, it was further improved by the addition of a second spindle, transforming it into what was called a "two-handed wheel," by which an expert spinster could spin two threads at once.

Describing this wheel, Mr. A. J. Warden, author of "The Linen Trade, Ancient and Modern," says:—"The frame of the machine stood on three feet, on the right of which, facing the spinner, was a spoked wheel about two feet in diameter, with the rim slightly hollowed outside. Rapid motion was given to the wheel by a wooden rod or crank, connecting the axle of the wheel to the treadle or footboard, and moved at will by the foot of the operator, much in the same way as a foot-turning lathe is moved. On the left were two pirns or spindles, one for each hand, for receiving the yarn as it was spun, driven by means of bands of gut, or cords of flax or woollen yarn, highly twisted, passing round the rim of the wheel and their axles. Each pirn or spindle had a flyer for twisting and guiding the thread before it was wound upon the bobbin, which was a hollow reed slipped over the axle and fitting rather closely to it. The fly went round with great rapidity, whilst the bobbin, being kept back by the strain of the thread turned round upon the axle, only as fast as it was let out by the spinner. This depended on the degree of twist intended to be given to the thread, and the expertness of the spinner. The rock or distaff with the flax wound round it in the manner best adapted for admitting of the filaments being readily drawn out by the spinner, was placed above the pirns, and both hands were employed in drawing out the fibres and forming the threads. The threads, after being carried through a throttle or opening in the end of the spindle, were from time to time shifted along the flyer by means of small pieces of bent wire attached to it for the purpose of filling the bobbin regularly with the yarn as it was spun. During the operation, the spinner moistened the threads regularly with saliva, the better to unite the fibres and improve the appearance

of the yarn." The same writer says that "the last improvement on the Saxony or flax wheel was the application of Arkwright's principle by rendering the flyer automatic in spreading the yarn on the bobbin, which saved the time necessary in moving the thread from one of the small bent wires on the flyer, to another, and at the same time performed the operation more equally."

The above brief sketch of the early history of spinning is introduced to show the connection of the modern system with its predecessor; in fact to show the continuity and essential oneness of the two systems, notwithstanding their apparent radical differences. They stand in relationship to each other as the child to the man. Though the outline of the sketch is to a considerable extent conjectural, it will fall sufficiently near the facts as, in the main, not to transgress the probabilities of the case. This course has been adopted and will be carried through the remaining portion of this essay, because it is believed that an exposition of the growth of the system, showing the defects successively encountered and the means adopted for their removal, will greatly help the reader to comprehend the purpose and functions of each machine and its several parts. To a student approaching the subject for the first time, the innumerable parts, and the complexity of their movements, present an almost incomprehensible and insoluble problem to his mind. Beginning the study, however, with the simplest manifestation of the art, and tracing it upwards to its highest or present development, its difficulties to a large extent disappear; the reason of every change is rendered apparent, and the functions of the added parts made clear; thus showing, when the termination of the investigation is reached, a beautifully ordered system whose complex movements constitute one harmonious whole, that must command the highest admiration from any mind capable of appreciating a display of the results of mechanical skill and genius, such as the world in its history cannot elsewhere display.

CHAPTER VIII.

THE MODERN SYSTEM OF SPINNING.

Commencement of the modern system.—Quality of hand-spun yarn.—Kay's inventions, the first impulse to improvement.—Scarcity of yarns.—Hargreaves' jenny.—Description of the jenny; its operation.—The single-thread hand-spinning wheel Hargreaves' model.—The Saxony wheel probably unknown to him.—Description of the Saxony wheel, single and two-thread.—Extensive adoption of Hargreaves' invention.—Richard Arkwright; the barber's shop a good school; itinerant hair-dealing; the Saxony wheel the model of Arkwright's invention.—Arkwright's claims as an inventor disputed.—Arkwright's labours; his assistants.—Description of his invention.—Comparison between the jenny and the water frame.—Paul and Wyatt's labours suggestive to Arkwright.—Arkwright not the inventor of the flyer; his adoption of Coniah Wood's traverse; the principle of the water frame adaptable to roving, slubbing, and drawing.—The progress of invention.—Haley.—Samuel Crompton.—His combination of Hargreaves' and Arkwright's inventions, and improvements upon them.—The jenny adapted for a slubbing frame; description.—Improvement of the roving frames.—Baker's inventions.—Hargreaves of Tottington.—Kelly's application of water power to the mule.—Wright's improvement; the squaring band.—Steam power.—Kennedy's improvement in fine spinning mules.—Transfer of spinning from females to males.—Manual requirements of the mule.—Eaton's coping motion.—The self-actor mule.—Its requirements.—The counter faller.—Differential motion of the spindles.—The self-acting mule a mechanical triumph.—Its qualities.—Roberts' genius.

THE modern or mechanical system of spinning properly commences with the invention of the jenny by James Hargreaves of Blackburn. The distaff and spindle had long been superseded by the hand or Jersey wheel, which had been brought to this country from the continent. Hand spinning attained its perfection with this wheel, as though an improvement upon it was invented by which two threads could be spun at one time, this was not extensively adopted, except in the flax-spinning districts, probably because it required the exercise of a greater

degree of skill and expertness than most of the spinners of the day could acquire, and possibly more difficulty also was experienced in dealing with cotton than the larger fibres of flax and wool. The single thread wheel in its simplest form had long been in use for spinning wool and flax, when the introduction of Indian muslins and other cotton fabrics to Western Europe, and the quick popularity these attained, suggested its adaptation to cotton spinning for the manufacture of imitations of the Indian cloths. It was soon, however, discovered that the new fibre was so radically different from those already in use that any hopes of success that might have been entertained of making warp yarns of cotton were quickly abandoned. Experiments, however, showed that a thread could be spun that would serve for weft, or filling, for warps of flax. The union fabrics thus produced were very good imitations of calicos, the heavier classes of Indian fabrics, so named from the district of Calicut, from which they were brought. The linen warp made the imitations actually more durable, and gave them a hold upon public favour which they retained until the progress of invention led the way to greater successes, and the ultimate defeat of the Indian spinners and weavers upon their own fields.

The hand spinners acquired a considerable degree of skill in spinning cotton wefts, making a round, solid, and even thread—regard being had in making this statement to the simple appliances used in the production. As might be expected, however, all degrees of excellence were found amongst them. The means by which these good results were secured has not often been noted by writers upon the subject. This was the passage of the yarn being spun between the surfaces of the finger and thumb of the spinner, by which the fibres as they were being twisted were consolidated by the slight pressure to which they were subjected, whilst the surface of the thread was rendered smooth by the extremities of the fibres being forced down upon the surface of, or into the body of the thread.

It has often been pointed out that the invention of the picking stick, and the addition of shuttle boxes to the lathe of the hand loom, by Kay of Bury, not only dispensed with one weaver in the production of wide cloths, but also enabled every single weaver to more than double his production of work immediately. The effect was such as might easily have been anticipated. The industry was to a great extent disorganized; and spinning, from being a branch subordinate in importance to that of weaving, became the best paid division of the trade. The scarcity of weft everywhere experienced gave a great stimulus to invention in connection with spinning; but for a long time very little success attended the efforts made to effect improvements.

The extending commerce, the growing wealth, and the increasing population of the country during the eighteenth century prevented any readjustment of the relations of the spinning to the weaving branch, or return to the former conditions of equilibrium. Weavers were unemployed a great part of every day, the time being spent in wandering over the country seeking weft amongst the spinners; whilst the latter, though there was a considerable increase in their numbers, owing to the comparatively large sums they were enabled to earn, scarcely cared to work more than half their time. It was in this state of the trade that Hargreaves' invention appeared, promising relief from the most pressing difficulty of the trade. The story of the persecution encountered by this genius in humble life, whose inventions entitle him to be regarded as one of the greatest benefactors of mankind that ever lived, do not properly come within our cognizance in this place; but a brief description of his jenny will be useful to the inquirer, not only because of its being the first departure of importance from the single thread wheel, but because it will show its intimate relationship to the system which it superseded, and also the close adherence of successive inventors to the type of the machine he constructed.

The illustration (Fig. 56) shows the jenny in probably the most perfect form it attained before it was superseded

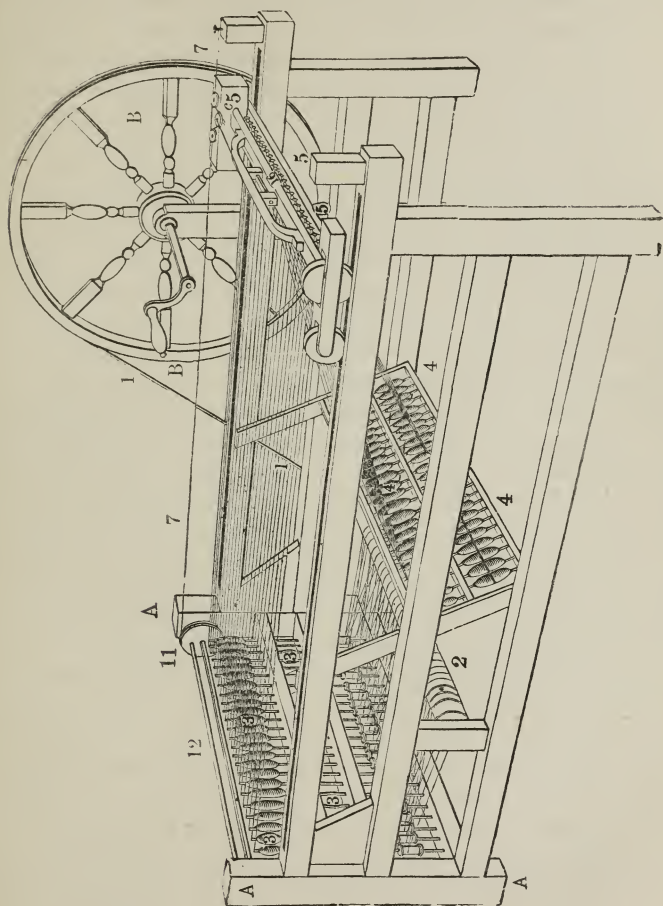


Fig. 56. Hargreaves' Jenny improved.

in its turn by Crompton's mule. As represented, it contains several improvements not of Hargreaves' invention. The mechanism is contained within the oblong frame, A,

and is exceedingly simple, consisting of the large grooved driving wheel, B, turned by the handle upon its axle, from which power is transmitted by the rope or band, 1, to the tin cylinder, 2, extending horizontally across the frame. From this cylinder endless bands are passed round the wharves upon the spindles, 3, arranged in vertical order at the extremity of the frame, A. A creel, 4, to contain the rove, was fixed inside the frame at such an angle of inclination as to deliver the material with facility to the carriage, according to requirement. This carriage was composed of two cross rails, one placed beneath the other, and resting upon the blocks, *cc*. These were mounted upon two wheels each, which ran upon rails fixed upon the tops of the parallel sides of the frame. This arrangement allowed the carriage a horizontal traverse from the tips of the spindles, of five, six, or seven feet, according to the size of the frame. The upper of the two cross rails, 16, forming the body of the carriage, had its under side grooved in the direction of its width for the reception of the plies of rove. The lower piece had corresponding projections upon its upper surface, which fit into the grooves just mentioned, and prevented any further delivery of rove after the quantity requisite for a "draw," or one traverse of the carriage had been given out. Small cords attached to a handle placed upon the middle of the upper surface of the top piece, and underneath the arched bar which extends across it, thence passing over sunk pulleys, connected the upper and the lower bars. Pressure upon this handle from the left hand of the spinner raised the lower rail into the position to retain the rove, whilst a spring catch held it there until it was released to deliver more. At the rear of the frame, and over the tops of the spindles, was a horizontal rail, which had its pivots in the frame on which it was arranged to turn. It had a flange at each side, one of which, 11, was grooved, thereby forming a pulley. Into these flanges a wire, 12, was fixed, at a short distance from the edge, which extended from side to side.

This was the original of the present faller wire, whose function is to guide the threads upon the spindle, and to build them into the form of a cop. It was operated by means of the cord, 7, which extended from the front of the frame over the pulley.

The jenny was worked by one person, who took up his position in front of the frame. The rovings were then drawn between the "clove" or clasp bars of the carriage, and attached to the spindles, the carriage having first been placed in position for commencing work that was at the end of its traverse, nearest the spindles. The bottom bar having been lowered, the carriage was drawn away from its position, until a proper quantity of rove to form one "draw," or length of yarn, had been given out, which was regulated by a mark upon the side of the frame. The lower bar was then raised, the rove held, and the spindles set in motion by the spinner turning the wheel, B, at the same time commencing to draw the carriage further out from its position near the spindles. Thus the attenuation and twisting of the rove went on simultaneously, until the requisite degree of fineness was attained, when the outward traverse of the carriage was stopped, the spindles being kept in operation for a short time longer, in order to impart sufficient twist to the thread. In the yarns intended for warps this was much more than for wefts, in which the same degree of strength was not required. When this twining had been completed, the carriage was slightly backed, the guide or faller wire, 12, was gently brought down upon the threads, by means of the cord, 7, depressing them to the required level; the wheel, B, was then turned slowly round, causing the spindles to wind up the thread as the carriage returned to its first position. This completed the first series of operations, and by their repetition the cops were formed.

It will be obvious from this description that Hargreaves followed the operations of his model, the hand spinner upon the single thread wheel, as literally as possible, whilst

substituting a mechanical for the manual process. The spindles were fixed in a frame, were turned by a large hand wheel, and the rove attenuated by the draught of the retiring carriage, the equivalent of the hand of the spinner. The winding was equally an imitation, the returning carriage bringing in the spun threads in a manner analogous to the movement of the spinner's hand. These remarks are by no means intended to be depreciatory; on the contrary, they are really laudatory. This illiterate peasant, living on the moorlands in the neighbourhood of Blackburn, in a time anterior to railways, or even good roads, and when almost the only means of communication between one district and another was by saddle and pack-horses, and when newspapers were a development of civilization yet in the future, could have few facilities for acquiring mechanical or any other kind of knowledge. The uneventful tenour of the lives led by the peasantry in these districts would rarely be suggestive of original thought or enterprise. That Hargreaves should in these circumstances have succeeded in solving a problem which had hardly even been suggested before, is highly creditable to him, and stamps him as a man of genius of a very high order. Though the jenny was his chief work, as has been intimated previously, it was not his only achievement in improving the rude machinery employed in the manufacturing processes of his day. By some writers Hargreaves' arrangement of the spindles in a vertical position is regarded as perhaps the greatest part of his invention. It cannot, however, be fairly regarded in this light, as this disposition of the spindle is simply an unconscious reversion to the position of the spindle in its earliest form, as shown in Fig. 53.

It is probable that the single thread spinning wheel was the only one familiar to Hargreaves. Had he been practically acquainted with the domestic flax wheel, otherwise called the Saxony or Leipsic wheel, in which great improvements over the single thread wheel in common use had

been effected, it is more than probable that he would have made that the basis of his efforts. In the flax wheel, by the introduction of a bobbin and flyer (Fig. 57), the twisting of the thread and its winding on the bobbin proceeded simultaneously and continuously, instead of intermittently, as in the common wheel, and Hargreaves' development of it, the jenny.

The driving wheel of the Saxony spinning frame was worked by a pedal or foot-lever, with connecting rod and crank, and was grooved for the reception of two endless bands, one of which drove the spindle, and the other the bobbin. The following (Fig. 57) shows that the bobbin and

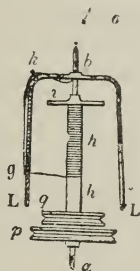


Fig. 57. Spindle, flyer, and bobbin.

flyer of this machine was almost identical with that now in use in the best frames of to-day. The spindle, *a b*, carries a large wharve, *p*, on its lower part, and on its top or extremity the flyer, *g k f*, is mounted. Flyer and spindle, of course, move at one velocity. The bobbin, *h*, has its lower flange grooved, forming the wharve, *q*, by which it is driven. This wharve, *q*, being of less diameter than the wharve, *p*, upon the spindle, the bobbin revolves at a higher speed. The flyer was tubular at the end, *b*, the tube terminating in a small orifice at *i*, which permitted the thread to emerge, and be thence carried over a tooth of the heck of the flyer, of which the leg, *g*, was composed. In operation the pedal was acted on by the foot rotating

the driving wheel, the bands from which transmitted the motion to both spindle and bobbin, the former making about six revolutions to the latter's eight, both these resulting from one revolution of the driving wheel. The rove was fed to the revolving spindle at *b* by the spinner, from the rock or distaff, whilst it was twisted as fast as it left her hands, entering the tube at *b*, emerging again at *i*, whence it was conducted around one tooth of the heck at *k*, thence over another at *g*, after which it passed upon the barrel of the bobbin at *h*. It will be seen that there was no arrangement for traversing the bobbin upon the spindle, by which a succession of even layers could be put upon the bobbin. The traverse motion was not yet invented, consequently when a given amount had been wound upon the barrel at *h*, the thread was moved over another tooth of the heck, thereby filling another portion. Sometimes this frame had two spindles, by which an expert spinner was enabled to spin two threads at a time, as both her hands were left at liberty to draw the rove from the distaff. The spindles were arranged horizontally, as in the common wheel. This wheel may yet be seen in many country districts of Wales, Scotland, and Ireland, and sometimes, though rarely, in England. In all these places it is now mostly used for spinning wool for hosiery purposes and domestic use.

After the first fever of excitement resulting from the invention of Hargreaves' jenny had subsided, it was quickly adopted, as it was found that one person could spin as much as ten, fifteen, or even twenty persons using the old method. But even this amount was not sufficient to meet requirements—the yarn obtained from the jenny only formed indifferent warp yarn, though serving very well for weft. There was consequently room for the invention of a machine capable of spinning a strong, solid cotton warp yarn. This was the chief requirement now needing to be satisfied to enable the English spinners, weavers, and merchants to successfully compete with the

cotton productions of India, which were being introduced into this country in large quantities by the East India Company. Such was the state of matters when the attention of Richard Arkwright, the Preston barber, was directed to the subject then occupying almost all men's minds, namely, the improvement of spinning and weaving machinery.

Arkwright's business of a barber was highly favourable to his success in the new pursuits in which he was about to engage, and was even probably the cause of his turning his attention to them. In his day a barber's shop was a reservoir of news, and from which also intelligence of every new event was disseminated throughout the district. Here he could not fail to learn of the invention of the Blackburn weaver, and the excitement it had produced, as the locality in which it had occurred was only ten or twelve miles away. But the barber's shop was also a capital school in which to study human nature ; and here, doubtless, was developed that extraordinary shrewdness which served him so well in after life, and enabled him to amass a colossal fortune where his contemporaries, from equally great, if not greater inventions, reaped only disappointment, vexation, and misery. The then prevalent fashion of wearing wigs gave Arkwright an opportunity of enlarging the sphere of his observations and increasing his knowledge. As he was a wigmaker and a dealer in human hair, he occasionally travelled over Lancashire and the adjoining counties, purchasing the raw material for this branch of his business. This gave him some experience of buying and selling,—in fact, gave him what Hargreaves and Crompton entirely lacked, a commercial training which was another prominent factor in contributing to his subsequent success. His birth and residence at Preston, then a centre of the linen manufacture, during the early years of his life, doubtless afforded him an opportunity of becoming acquainted with the Saxony spinning wheel, which he would be shrewd enough to see afforded a much better basis on which to commence operations for

improvement and invention than the one selected by Hargreaves. In the first place it was a continuous spinning wheel, not having to stop to wind up the spun lengths of yarn. In the second the thread it produced was rounder, firmer, and the fibres composing it more consolidated than could be obtained either from the common hand wheel or Hargreaves' jenny. This was owing to the thread being passed through the tube and around the heck wires of the flyer, which greatly helped to make the thread both dense and smooth: the very qualities that were wanted in warp yarns. He could hardly fail to see these advantageous points, and make his decision accordingly.

Thus we arrive at the sources of the two principal types of modern spinning machines: intermittent, represented by the mule, which has its origin in the common hand wheel; and the continuous spinning frame as now existing in the throstle and the ring frame, whose progenitor is the Saxony or hand flax wheel.

Arkwright's claims as an inventor have been strongly disputed, it being alleged against him that he purloined and utilized the ideas of better men than himself, and undoubtedly the evidence strongly favours that view of the case. It is well known that he employed several people to aid him in his investigations, and whether the inventions which he ultimately secured and reaped the profits of were the outcome of his own or his employés' ingenuity cannot now be known. Certain, however, it is that the results achieved were obtained under his guidance and at his expense.

It is not probable that Arkwright was engaged upon his celebrated spinning machine more than two years before he had, with the aid he employed, so far perfected it as to secure a patent for it in 1769. This would show that the tumults and excitement springing out of Hargreaves' invention were the exciting cause of his thoughts being turned to the subject. King, the watchmaker, made for him his first rude model in 1767. Hargreaves had invented his jenny in 1764, and the tumult and rioting, com-

menced in 1767, continuing for some time, causing him to leave the county in 1768. Arkwright, afraid of meeting with the same sort of treatment, followed Hargreaves to Nottingham, along with a friend who, for some time, had been aiding him with capital. This friend was John Smalley of Preston, who advanced nearly all the money required for the experiments, until his means becoming exhausted it became necessary to obtain other aid. Smalley, after leaving Arkwright in 1775, started a cotton mill at Holywell in North Wales. At Nottingham, in a small factory in Woolpack Lane, with the help of Messrs. Need and Strutt, who afterwards became his partners, Arkwright so far perfected his device as to obtain a patent for it at the date mentioned above. The machine thus protected was the parent of the second type of our spinning machines, namely, the modern throstle and ring spinning frames. As such it is deserving of detailed notice.

The following Fig. 58 is from Arkwright's specification of 1769, and probably represents the machine in the condition to which he had brought it up to that date. It was constructed to be turned by horse power. The description is also from the specification. "A is the cog wheel and shaft, which receive their motion from a horse. B, the drum or wheel which turns, C, a belt of leather, and gives motion to the whole machine. D, a lead weight which keeps, F, the small drum, steady to, E, the forcing wheel. G, the shaft of wood which gives motion to the wheel, H, and continues it to, I, four pairs of rollers (the forms of which are drawn in the margin), which act by tooth and pinion made of brass and steel nuts fixed in two iron plates, K. That part of the roller which the cotton runs through is covered with wood, the top roller with leather, and the bottom one fluted, which lets the cotton, &c., through it; by one pair of rollers moving quicker than the other, draws it finer for twisting, which is performed by the spindles, T. K, the two iron plates described above. L, four large bobbins with cotton rovings, are conducted between rollers at the back.

M, the four threads carried to the bobbins and spindles by four small wires fixed across the frame in the slip of wood, v. N, iron levers with small lead weights hanging to the rollers by pulleys, which keep the rollers close to each other. O, a cross piece of wood to which the levers are fixed. P, the bobbins and spindles. Q, flyers made of wood with small wires on the sides, which lead the thread to the

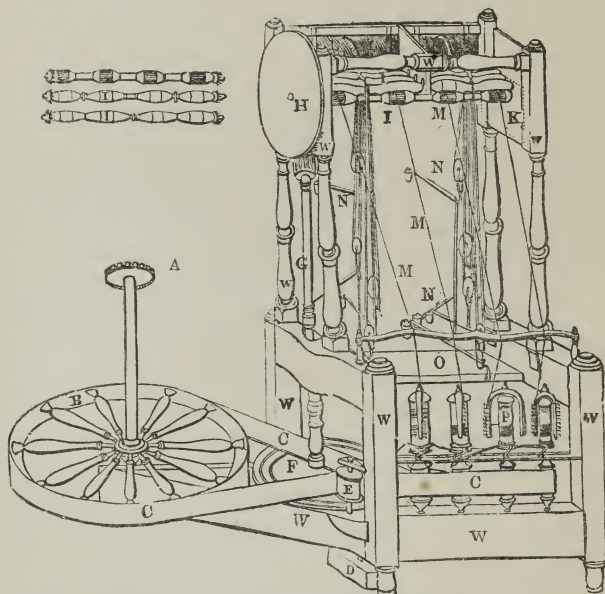


Fig. 58. Arkwright's Spinning Frame.

bobbins. R, small worsted bands put about the whirl of the bobbins, the screwing of which tight or easy causes the bobbins to wind up the thread faster or slower. S, the four whirls of the spindles. T, the four spindles, which run in iron plates. V, explained in letter M. W, a wooden frame of the whole machine." Such is the great inventor's description and illustration of his spinning machine; it is not very lucid, and a further description may be permitted.

Fig. 59 is a section of the machine when it had probably been further improved. The four pairs of rollers, A, A, by which the sliver was drawn or attenuated, were composed of brass and steel, and connected by small pinions: the bottom ones were covered with wood and

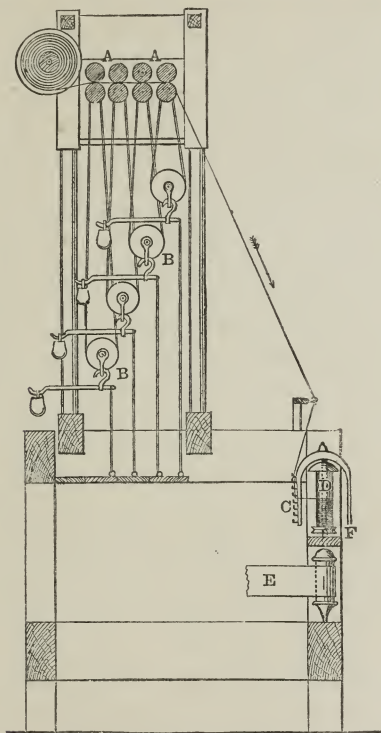


Fig. 59. Arkwright's Spinning Frame. Section.

fluted, and the top ones were covered with leather, as is the custom at the present day. The upper rollers were kept in contact with the lower ones by means of the weighted cords and pulleys, B, B. As the sliver was delivered from the rollers it was twisted into a thread by

the flyer, c, upon the spindle, and wound upon the bobbin, d. The bobbin was fitted loosely upon the spindle, and its revolution retarded by a friction band working upon the bottom flange, f, and which was brought to the requisite state of tension by a screw pin to which the end was attached. This also caused the yarn to be wound upon the bobbin tightly. One leg of the flyer, c, had pins inserted in it to guide the yarn upon the barrel, this being in fact the actual method employed in the flax wheel, as already seen. The yarn was thus wound upon the bobbin in successive stages, the bobbin being stopped to effect the transfer of the thread from one position to the other.

A few words of comment and comparison between this machine and that of Hargreaves may be permitted. In the first place allowances must be made for the crudeness of the drawing, which does not do justice to the invention, and which incidentally shows what has since been called mechanical drawing in a very early stage of its development. Hargreaves found the spindle in the hand wheel arranged in a horizontal position, as shown in both forms of that machine. One of the great merits and distinctions of his invention is that he changed this to a vertical position. Arkwright, who followed him, clearly borrowed and adopted this arrangement in his frame. Hargreaves in attenuating the rove adhered to the principle employed in hand spinning; namely, drawing it by the recession of the carriage from the spindles. Whether he had ever or not heard of the attempts of Paul and Wyatt to accomplish this by means of rollers does not appear, but undoubtedly Arkwright had obtained a knowledge of it, and must, at the same time, have learned of its failure. What led the latter to renew the attempt cannot now be known, but he appears to have pressed the matter upon the attention of the mechanics he employed, and it is probably owing to his persistence that success was ultimately achieved. It is not clear whether he himself solved the problem, or owed it to his assistants, or whether it was

the result of their joint efforts. This, however, is now a matter of no importance, the world having secured the benefit of the realized idea, which is one of the greatest inventions of the age; and though it had been previously suggested, it was first practically embodied in Arkwright's spinning frame. The presumption, therefore, is almost entirely in his favour, and for his solution of the problem the world can hardly award him too much honour.

Roller drawing is the distinctive feature of his machine, and this has since been introduced into every other form of cotton spinning frames, and into many of those for dealing with other fibres. The rove in both the new forms of spinning machines was arranged in creels, Hargreaves' being placed inside the frame and Arkwright's superimposed upon it. In winding the spun yarn upon the spindle, Hargreaves adopted a guide wire, the parent of the modern faller, and the equivalent of the guiding fingers of the hand spinner; practically a multiple of them. Arkwright again utilized the best and most advanced form of achieving the same end, which he found existing in the differential speeds of the bobbin and flyer of the Saxony wheel. Arkwright has sometimes been credited with the invention of the flyer, but this is a mistake, it having been invented long before his birth. There exists in the library of the English Patent Office a small work written by Thomas Firmin, on "The Employment of the Poor," the frontispiece to which is a figure of a girl at a spinning wheel, the spindle of which carries a flyer, one leg of which forms a heck composed of guide pins for directing the thread upon the bobbin. When the mill at Cromford was started, the spinning frames Arkwright put into that place showed a great advance upon those first constructed, the winding being accomplished by the drag or frictional retardation of the bobbin, which was not driven by a band as in the Saxony wheel, but left to be drawn round by the yarn. The winding was also improved, the heck upon the flyer having been dispensed with, and a traverse rail introduced which

carried the bobbins up and down upon the spindles within the arms of the flyers, which thus automatically deposited the yarn in even layers upon the bobbins. Coniah Wood, who patented a spinning frame in 1772, was the first to introduce the traverse rail for the winding, and to dispense with the heck upon the flyer. Arkwright, whom Wood had for a considerable time assisted in his pursuits, as usual with him, quickly adopted this idea, adding an important improvement in a heart-shaped cam which rendered its action automatic, which it was not in Wood's invention. Hargreaves' jenny, even after its combination with the water frame of Arkwright in the mule by Samuel Crompton, in which it has been brought to the most wonderful degree of perfection, has remained essentially what it was in its original form, a spinning frame, with the insignificant exceptions of the slubbing "billies" and jack frames. One great merit of Arkwright's machine was its adaptability, with slight modifications, to use in several stages in the preparation of cotton for spinning. We find it first in the drawing frame, and afterwards in the whole series of the bobbin and fly frames: the slubbing, intermediate, and roving frame; and again, but without its distinctive feature, the drawing rollers, in the throstle doubling frame. To Arkwright must be awarded the credit of these adaptations, though he left much to do in perfecting the details of each machine to succeeding inventors.

As it does not fall within the scope of this short treatise to trace in detail the progress of mechanical invention—though the task would undoubtedly prove both interesting and instructive—by which the present stage of comparative perfection has been attained, haste must be made to deal with the facts and conditions of to-day. In the transit from the earliest days of the modern system to the present time, it may, however, prove useful to the student desiring fuller information to give the names of the successive inventors, and to outline the nature of the contributions each individually made to the sum of present results.

Hargreaves' invention had not been long at work before it was considerably improved by the introduction of the horizontal cylinder, 2, to drive the spindles and the grooved wheel B (Fig. 56), which were not originally in the jenny. They were invented and added by a man in a similar position of life, named Haley, residing at Hoghton, near Blackburn. The important part played by the cylinder for the transmission of motion to the spindles only needs mentioning to be appreciated.

But incomparably higher than all his contemporaries after Hargreaves and Arkwright stands the name and services of Samuel Crompton, whose invention of the mule spinning frame has proved of such vast importance to the world. The solution of the problem, if not the inception of the idea of spinning more than two threads at a time, as we have seen, belongs to Hargreaves; the realization of the attenuation of the rove by means of drawing rollers, by which these spindles could be supplied with the requisite material with facility and in the best form, must be credited to Arkwright; whilst the combination in one spinning frame of the best points of both of these inventors' machines is due to Crompton. But he was not merely a person who utilized the fruit of other men's labour, he was also a great inventor, as he showed by fixing his creel of rovings in the frame of his machine, and transferring his spindles to a moving carriage. This combination, along with his own improvements, made his frame immensely superior to either the jenny or water frame. In the first the attenuation of the rove could not be secured with the evenness that was desirable, and generally the outward traverse of the carriage was completed before irregularities could be removed by the process of stretching the thread. In introducing the roller system of drawing the rove, Crompton secured the best known means of accomplishing that object, whilst he retained the outward traverse of the jenny carriage as a reserve power wherewith to overcome the defects or irregularities that might remain in the rove after drawing by

the new system. The defective state of the means for preparing cotton in the preliminary stages left much to be done in the final process in the way of perfecting results. The water frame contained no means of overcoming these defects, but the mule was enabled to take out irregularities by means of the "stretch." This defect of the water frame was recognized by its inventor himself, and was the cause of the great devotion he paid to perfecting the preparation, and for his improvements in which the trade is deeply indebted to him. But all his labour in this direction was equally advantageous for his great rival's machine, the mule. The more perfect the rove, proportionately the more perfect would be the thread from the water frame, whilst in the mule it would be this plus the improvement obtained by the stretch. Hence the enormous success of the mule frame, which, when Arkwright's patents were set aside or expired, leaving it practicable to use his rollers and preparatory machinery, distanced its competitor on every side. It was only as further improvements in details took place, that the distance in merit between the two machines or systems of spinning began to diminish, and the water frame, which afterwards became the throstle frame, approached more nearly abreast with the mule. Within the past few years only has the contest become nearly level in spinning the lower ranges of numbers as to quantity and quality of production.

There is evidence sufficient to lead to a fair conclusion that Crompton independently invented the system of drawing the rove by means of rollers. In his first machines they were of wood, and of so crude a form and structure, that had he seen or even heard of Arkwright's method, he could hardly have failed to have made a better beginning. Crompton's rollers in this respect were speedily improved upon by Henry Stones, a mechanic of Horwich, near Bolton, who had probably enjoyed the advantage, denied to Crompton, of seeing Arkwright's water frame. Stones therefore introduced the metallic rollers of Arkwright's

frame into Crompton's mule, thus contributing greatly to its improvement. The same person also effected other improvements in the mule.

About this time Hargreaves' jenny was adapted to another purpose, that of preparing slubbings or rovings for spinning, which adaptation is illustrated in Fig. 60. This was accomplished by a person at Stockport, who mounted his spindles in a carriage like Crompton, which he placed to run upon the lower cross piece of the frame, A, instead of the top rail as in the jenny. Haley's cylinder, F, was used for driving the spindles, and Hargreaves' faller wire, 8, assumed a better form, and was placed in a more convenient position. The driving-wheel, E, was mounted upon standards fixed to the carriage, and was operated as in the jenny by the winch attached to the end of the axle. The strips of carded cotton were placed side by side upon an endless sheet revolving upon two rollers, and which carried them upwards to and beneath the roller, C, a light wood pressure roller called the billy roller, and which attracted some attention at the time. The frame containing these rollers occupied the position of the spindles in the jenny. The card ends passed between two bars, equivalent to the "clove" of the jenny. The upper of these bars, G, was raised to allow of their passage. When a sufficient length had been drawn through, the bars were closed again, and the portion of rove thus drawn off was attenuated as required, slightly twisted, and then wound upon the spindles. When the carriage was returned home in the winding process, a wheel, 5, ran under the lever, 6, which raised the sliding wires, 7, upon which the bar, G, was mounted, thus opening the clasp for the draught of another length of the carded cotton.

This illustration will serve to show how the component parts of every invention in the early days of the industry were transposed and interchanged from one to another, as the variations gave promise of improvement. The slubbing billy was a useful machine in its day, and maintained a

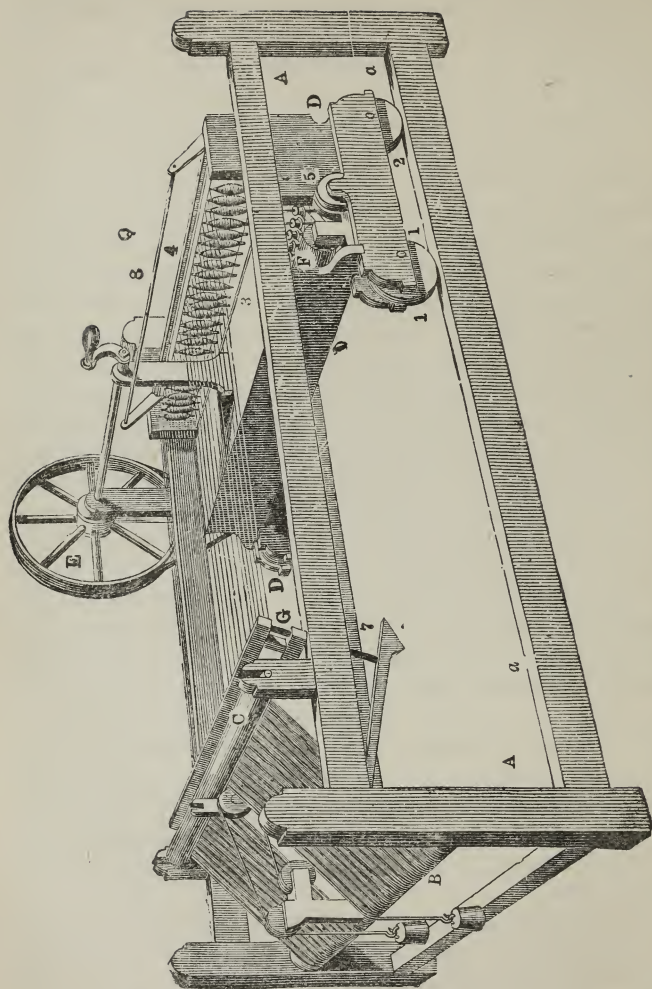


Fig. 60. The Slubbing Frame; a modification of the Jenny.

position in the cotton trade alongside Arkwright's slubbing and roving frames, until, by the invention of a more perfect system of differential driving of the spindle and bobbin in the fly frames, the latter were so much improved as to render their superiority incontestable. Then the slubbing billy disappeared entirely from the cotton manufacture, but in a modified and improved form it still exists in the woollen trade.

The difficulty of constructing the tin cylinders with accuracy, when it was desired to increase the length of the mules, was, for a short time, an obstacle to their further extension of size. This was, however, overcome by the invention of small cylinders, called drums, by a person named Baker, of Bury, which were arranged vertically in the carriage of the mule, and were driven by a stout band from a grooved wheel in the head stock. This admitted of the length of the carriage again being greatly extended. Success has, however, finally rewarded the efforts that have been devoted to the construction of cylinders, and these can now be made of any length; as a consequence this method of driving the spindles has again been reverted to, and Baker's drums have disappeared. Baker also invented the diagonal shaft, by which motion was transmitted to the rollers from the rim. This shaft dropped out of gear at the rim when the rollers were to stop. The introduction of this shaft was a great improvement, enabling much more accuracy to be obtained in the working of the parts, and giving opportunity for the yarn to be more highly perfected in the final stretch.

As yet the carriage had been brought out from the roller beam by various appliances, all more or less imperfect in their nature and action, and most of which left "the stretch" or second draw to be completed by the hand of the spinner. The stretch was longer or shorter according to the quality of the material and the counts of yarn being spun. The first appearance of the germ of the more perfect system of bringing out the carriage, which has

now been so long in vogue, was in the invention of a parallel scroll with a small conical one attached, by James Hargreaves, of Tottington, near Bury. "Hargreaves" is a common name in Lancashire, and though this inventor bore the same name and surname as the inventor of the jenny, and though only about nine miles of wild moorland separates Stanhill, the residence of the last-named, and Tottington, there is no reason to suppose that any family relationship existed between them.

The mule up to 1790 was purely a manual machine, operated by the hand of the spinner. Though the spindles were gradually increasing in number, yet they were few compared to what they became shortly after they were adapted for being driven by animal and water power. Mr. Kelly, of Glasgow, formerly of the Lanark mills, was the first person to accomplish this latter improvement. The way in which he effected this, was by means of a loose pulley carrying a catch, which at pleasure could be made to seize another catch fixed upon the axle. On this axle was a screw which worked into a wheel, and the number of teeth in which governed the number of revolutions of the rim by disengaging the rope from the fast to the loose pulley. The new arrangement enabled the mule to be largely increased in size.

This invention had hardly got to work before Mr. Wright, a Manchester mechanic, and formerly an apprentice of Sir Richard Arkwright, doubled the dimensions of the mule at once by placing the head stock, or rim, as it was then called, in the middle of the length of the frame or roller beam. The widening of the mule also brought another difficulty to the front. The carriage became of such a length that when being drawn out the extremities were apt to lag behind the centre portions unless the frame was made of great rigidity and strength, in which case it became too heavy to operate with facility. The consequence was that good work could not be made, and any kind was almost impracticable. This obstacle to efficiency

was overcome by the invention of the "squaring" band, which enabled the carriage to be brought out on a perfectly straight line, like the two sides of a parallel ruler.

Kelly's substitute for manual power was water, but with the enlargement of the mule, and the erection of special buildings or factories for containing them, eligible sites became difficult to obtain, and were often far from centres of population. Steam power began to be welcomed and extensively adopted, but it is curious now to note that the steam engine was first employed to lift water in order to pour it upon a water wheel, which turned the machinery, as this was thought to be the only reliable source of steady driving, and perhaps correctly so, in the infancy of the steam engine. It was not long, however, before such improvements took place in the latter as to dispense with the necessity of taking power from it by this roundabout method. Its direct application enabled mills to be brought to the centres of population, with which facilities, and a growing demand for yarns, spindles rapidly increased in number.

Up to 1793 no attempts were made to spin the finer yarns, say from 100^s and upwards, upon the machinery driven by water or steam power. At that time these higher counts began to be attempted by the more skilful spinners. Mr. Kennedy, one of the earliest of the Manchester machinists, and from whose paper on the life of Samuel Crompton some of the foregoing particulars have been gleaned, was a careful observer of the difficulties encountered in these attempts, and set himself to invent a remedy. One of these was the slow speed at which it was necessary the mules should work when spinning, say, 200^s, and which reduced the production to a small quantity. The rollers in this case could only make about twenty-five revolutions per minute and the spindles about twelve hundred. But when a sufficient length of roving had been drawn out for one length or traverse of the carriage, the rollers stopped, and the spindles were accelerated during the second draw or stretch. This acceleration of speed was

put in by the manual labour of the spinner. Mr. Kennedy, however, devised a plan by which it was automatically accomplished by the mule. His first idea was to adapt the principle of the arrangement of wheels termed the sun and planet motion, which was suggested to him by seeing it in Watts' steam engine. The low state of mechanical skill, and the consequent difficulties to be encountered in making the parts at that time, however, deterred him from the attempt, and he chose the simpler method of an arrangement of four wheels of unequal sizes for producing the same effect. This plan was partially successful, and by repeated improvements, made according to the suggestions of several persons interested, became approximately perfect. The wheels were first lifted in and out of gear with each other ; afterwards a clutch box was employed, which improved upon the previous arrangement considerably ; then Mr. Kennedy introduced the plan of three pulleys, one fixed on the small wheel, another on the larger one, and a loose one. By removing the driving strap from the loose pulley when the wheel was at rest, to the pulley on the smaller wheel, the rollers were set to work, and next to the pulley on the larger wheel, which accelerated the speed of the rim and the spindles until the thread was stretched and fully twisted, when the strap was again removed to the loose pulley, the machine coming to rest in order to allow the draw or length of yarn just finished to be wound upon the spindles, after which operations recommenced. Mr. Kennedy subsequently introduced his original idea of accomplishing this end by the sun and planet motion, which was regarded as a further improvement.

Spinning in the early days of the modern system was an occupation requiring great skill and care. In ancient times, when the instruments in use were the distaff and spindle and the old hand wheel, its pursuit was confined almost exclusively to the female sex, and during the first part of the transition period but little change took place. Hargreaves' jennies were generally worked by women and

children, as also were Arkwright's water frames. The successive improvements and enlargements, however, began to make them too complicated and cumbrous for females to handle, and hence necessitated a change in this respect. Another reason which expedited the transfer of this occupation to the hands of men was that with the increased production resulting from the use of the new machines, and the rapidly growing demand for yarns, it became a more profitable occupation than weaving, which began to fall more generally than before into the hands of women. Thus an industrial revolution which overturned a relationship of the two sexes that had existed for ages was quietly established.

The great skill and care needed on the part of the operative to produce good yarns arose from the fact that the principal movements in Crompton's mule, which had been quickly recognized as by far the best spinning frame, still required to be performed by the hand of the spinner, notwithstanding the improvements that had been effected. The building of the cop upon the spindle was the work of the attendant; the backing-off previously to winding was done by hand, as was also the regulation of the speed of the spindles during the latter operation, so that the winding should take place upon the different diameters of the cop without breaking the threads. The paucity of this skill caused steady progress to be made in the direction of rendering the mule more and more automatic. With the single faller wire it was found impossible to prevent the yarn running into snarls when the backing-off took place, and these could not afterwards be taken out. A simple device, the counter faller, remedied this. It was placed under the threads, and was raised at the moment of backing-off in order to take up the slack, and thus prevent the formation of snarls. In this it was to a great extent a success, but complicated the mule still further, and added another difficulty to its management.

One of the most important steps in advance was the in-

vention in 1818 of a copping motion by Mr. William Eaton, which took the entire operation of manipulating the winding of the threads from the hand of the spinner, rendering it automatic. More is implied in this than may appear at the first view. It necessitated in the first place a self-acting method of performing the backing-off at the finish of each outward traverse of the carriage, and before the winding commenced ; secondly, an automatic action of the two faller wires, the ascent of the counter faller, and the descent of the winding faller, or guide ; and, thirdly, a self-acting arrangement regulating the speed of the spindles according to the increasing size of the winding surfaces of the cop. Great credit is due to Mr. Eaton for the ingenuity displayed in this invention, as in many respects his methods of achieving these ends have formed the basis of the improvements that have led to the present more perfect plans.

The labours of Hargreaves, Arkwright, and Crompton had not long been presented to the public before the conception was formed that it was quite practicable to make purely automatic spinning machines which, without human aid, should perform all the operations involved in the production of yarn, and which should require nothing more than general superintendence. Having secured a steady, reliable, and untiring motor in the steam engine, these day-dreams could hardly be regarded as beyond the possibility of realization. The Rev. Dr. Cartwright, the inventor of the power loom, was the first who attempted to realize the vague ideas prevalent on this subject. His device was ingenious and highly creditable, but, as might be anticipated, was a failure. He was followed, with more approximation to success, by Messrs. Eaton, of Wiln, in Derbyshire, Mr. De Jongh, of Warrington, Mr. Buchanan, of the Catrine mills in Scotland, and Mr. Smith, of Deans-ton. An American inventor, Dr. Brewster, was also in the field in pursuit of the same object.

But the merit of solving this difficult problem belongs almost entirely to Mr. Richard Roberts, of Manchester,

who had for some time also been devoting his attention to the matter. His first patent was taken out in 1825, and a second for extensive improvements in 1830. Roberts' mule was so distinctly superior to those of all competitors that it quickly secured a large amount of favour from the trade. But this was not until after the improvements covered by the second patent had been made.

The mule, as already shown, had been brought to a high state of development as a machine which yet required manual assistance in its operation. The problems, therefore, which confronted the inventor in his efforts to dispense with the latter necessity were: first, the construction of a reversing arrangement which should unwind the spiral of yarn upon the top of the spindle previously to commencing the winding of each stretch; secondly, the invention of an arrangement or mechanical appliance which should govern the movement of the faller wire so as to build the yarn upon the spindle in the form best suited for subsequent processes, which had already been established as the cop—a cylindrical figure coned at each end. This was also required to be firmly constructed, of good shape, and correct proportion. And, thirdly, an appliance was required that should vary the speed or rate of revolution of the spindle according to the enlarging diameter of the winding surface of the cop. When it is considered that not only were these intricate problems to be separately solved, but that, when this had been accomplished, the different pieces of mechanism had to be combined in one machine in such a manner as to work in perfect harmony in relation to one another, some idea of the intricacy and delicacy of the task may be formed.

The invention of the counter faller was the first great step towards the solution of the problem of winding. This, like the ordinary faller, was a horizontal wire extending the length of the spindle carriage, but, unlike the other, it was placed beneath the threads, and about two or three inches from the tops of the spindles. Its function, now so

well known, was to rise and take up the slack in the yarn caused by the "backing-off" or unwinding of the spiral of yarn upon the uncovered portion of the spindle, as previously referred to, and to retain the yarn in such a state of tension as to prevent it from running into snarls until the winding process had taken it up. During the progress of the latter the top faller would gradually rise, and the counter faller descend, until the winding was completed, when each would have regained their original position, there to rest until another draw or outward traverse of the carriage, forming another length of threads, had been completed. The top faller was actuated by means of compound levers, acted upon by rotary cams, which brought it down upon the threads, after which its movements were governed by a lever and friction roller, which traversed an inclined plane called "the shaper." This acted upon the faller, through the lever, in a different manner at every stretch, by which the successive layers were built up in such a manner as to form a well-shaped and firm cop, in many respects superior to the best that could be produced by hand.

The variable revolution of the spindles during winding was effected by a small drum placed at the end of the carriage near the headstock, to which the ends of two cords were attached, and coiled round it in opposite directions so that when one was being wound on the other was uncoiling. One cord was extended to the back of the headstock, and to its extremity a weight was suspended to act as a counterpoise, drawing the cord off the drum as the carriage drew away from the rollers, during which time the other cord was being wound up. This drum was also connected with some toothed wheels which were brought into gear with that part of the mechanism that operated the spindles during the time the yarn was being backed-off preparatory to winding on the spindle. The cord which caused the winding-on drum to revolve during the running in of the carriage had one end attached to the radial arm of a

quadrant which described an arc whilst the winding-on drum was receding from the point of attachment in a straight line. As the carriage receded the cord was uncoiled, causing the drum to revolve and thence the spindles. The amount of rotation of the spindles was regulated by the length of rope to be uncoiled. Assuming that all the parts were arranged for the commencement of work, and the spindles bare, the maximum number of revolutions would be required to wind on the length of a stretch or draw, but for winding the next a diminished number of revolutions would be required, owing to the winding surface having been increased by the previous layer. This was repeated with each succeeding layer until the bottom or base cone of the cop was completed. After this the movement was uniform until the completion of the cop or set. An accurate differential motion analogous to, but in its details radically different from that already described in connection with the roving frame, was therefore required and found in this arrangement. In this case the decrease of motion in the spindles was obtained by lessening the length of cord to be uncoiled from the winding-on drum. This was effected by making the point of the radial arm change its position with the addition to the cop of every stretch, so as to effect the required diminution in the length of the rope.

The first self-acting mule was one of the greatest triumphs of mechanical genius that has ever been achieved, and as a display of the power of the inventive faculty in man's nature surpassed anything accomplished up to that time. This statement hardly requires even that limited qualification, as though great advances have since been made in many branches of mechanical industry, nothing yet surpasses the spinning mule in the number and variability of its actions, the admirable concert of its parts, or the excellent results achieved by it.

The new machine was a perfect spinner; that is, it accomplished every part of the process without manual

help. Hargreaves' jenny and Crompton's mule required the aid of the operative to perform several processes. The inventor of the new mule dispensed with all necessity for this help, and transformed the operative spinner into a superintendent merely. Its chief features of difference from Crompton's mule, as improved up to that time, were :—1st, in the mechanism by which the faller and counterfaller were respectively depressed and elevated in backing-off and winding ; 2nd, the regulation of the movements of these wires so as to make a well-formed cop ; 3rd, the arrest of the twisting revolution of the spindles, reversing them for backing-off, the stoppage of this movement also, and a second reversal of the direction of the revolution of the spindles, with a slow and differential movement for winding up the yarn ; and 4th, when all these were successively completed, the means by which they were automatically started anew.

The amount of inventiveness embodied in the new mule considerably exceeded that shown in the jenny or Crompton's machine, great as this was in each instance. Arkwright, as we have seen, was only to a limited extent a true inventor, being more distinguished for his ability to utilize the inventive faculty and labours of others, so that he can hardly be brought into the comparison. It must, however, be said in favour of Hargreaves and Crompton, that Roberts had facilities placed within his reach by the progress of mechanical science, and the improvement of machine construction, many advantages from which they were debarred. His genius was therefore comparatively unfettered, and hence achieved superior results. The value of his invention, however, can hardly be regarded as so great to the world as that of his predecessors, though the inventive skill manifested in it was superior. Hargreaves showed mankind how to do something essentially new and unthought-of before ; Crompton wonderfully improved upon Hargreaves' plan, both in the manner of its action and the extent of its results ; Roberts made a great step forward on the labours of both.

CHAPTER IX.

THE MODERN MULE.

Present comparative perfection of the mule.—The head-stock, with illustrations.—Means of actuating the drawing rollers, spindles, and carriage.—Stopping the carriage and the revolution of the spindles.—Backing off; movement of the faller.—Drawing in of the carriage.—Winding mechanism.—Harmonious operation of the parts in action.—More detailed description; development of the various parts.—The faller wire motion, and its operation.—Building the cop.—The counter faller wire.—The backing-off mechanism.—The winding quadrant and its function.—Recent removal of several imperfections.—Copping apparatus controlling the backing-off movement.—The loose incline.—Improvement in the backing-off chain tightening motion; causes of its requirement.—Imperfection of the winding apparatus as left by Roberts.—Successive improvements.—Messrs. Platt Bros. and Co.'s automatic nosing motion.—Improvement in the click wheel.—The stretching process in early mules; succeeded by the "gain."—The former plan retained for "medium fine" and "fine" mules.—"The jacking motion," and its adjuncts, the jacking delivery and the winding delivery motions of the rollers.—Retention of the hand mule for the finest yarns.—Its improvement.—Self-acting mule for finest yarns.—Backing-off and winding.—The quadrant and its improvement.—Automatic regulation of the fallers; the lifting motion; locking and unlocking of the faller; winding; and backing off.—Speed of the parts; changes; replacement.

THE brief review just given of the development of our principal spinning machine brings us to the period in which it is found with the essential principles and general structure and form it has since retained. All subsequent improvements, though considerable, have been in details. These have been perfected almost to the highest degree possible, and it would seem that little remains for succeeding inventors to accomplish in its further improvement, and this idea appears to be confirmed by the fact that of late years attention has been greatly diverted to the improvement of the flyer frame, in both its old form, and as

modified in the ring spinning frame. As, however, the mule is, and must long remain the most important spinning frame of the series, it will be well to examine it in detail before proceeding to the consideration of the claims of its rivals.

The following illustrations and description are reproduced from the article on "Cotton Manufactures," by the present writer, in Messrs. Spens' "Encyclopædia of Manufactures and Raw Materials," referred to previously:—

Fig. 61 represents a side elevation of the mule head-stock, with the transverse section of the carriage, shown as running in, and in the act of winding. The drawing-rollers and roller-beam are also seen in section. Fig. 62 is a front view. In Fig. 63 is seen a corresponding plan of the mule, showing the head-stock in the middle, and having spindles working on each side.

The driving power is communicated to the machine through the horizontal first-motion shaft, on which are the fast and loose strap pulleys A B.

When the carriage M has run in to the roller-beam, or drawing-rollers, the front of which series is seen at c^8 , the driving strap is on the fast-pulley A, though a portion extends to the loose-pulley B. Motion is communicated to the drawing-rollers by the small change bevel-wheel c, driving the large bevel-wheel c^1 , running loose on the horizontal shaft c, and connected with the front line of drawing-rollers.

The spindles are also driven from the chief motor shaft by the double-grooved cord-pulley, or rim, A^2 , on the extremity of the shaft, carrying the bevel-wheel c. From this pulley, an endless cord a passes downwards, beneath the guide-pulley a^1 , thence to the oblique cord-pulley a^2 , as seen in the carriage M, and to and around the tin roller a^3 , keyed on the horizontal shaft J, which carries the tin cylinders J^1 used for driving the spindles. Thence it passes forward, and around the carrier-pulley a^4 , fixed to the front of the frame, then along the floor to

the guide-pulley a^5 at the back of the headstock, and thence to the rim-pulley A^2 . This completes the circuit of movement by which the spindles are operated.

Whilst these movements for the spindles and drawing-rollers are going on, the small spur-pinion c^2 , keyed on the front roller c , drives the spur-carrier-wheel c^3 , which drives the spur-change-wheel c'' , fixed on the boss of the smaller spur-wheel c^4 ; the last-named c^3 and c^4 run loose on studs, fixed to the movable weight-lever c^6 , hinged on the front roller-shaft c , the spur-wheel c^4 gearing into the spur-wheel c^5 , which is keyed on the shaft H , called the back, or drawing-out shaft, running the full length of the mule, and upon which are fixed three scroll-pulleys, one being seen at c^7 , and one at each end of the shaft. These pulleys have a rope attached to and wound upon them, the other part being passed round the guide-pulleys, turned back, and attached to the carriage, for the purpose of traversing it outwards as the yarn is spun.

When the carriage arrives at the extent of its stretch, *i.e.* is at the point of its traverse the furthest from the front drawing-rollers, the faller-shaft comes into contact with the incline E^1 , fixed on one end of the beam-lever E , pressing it down, so that it turns on its fixed centre E^2 . On the opposite end, is a similar incline E^3 , also a stud E^4 , on which hangs the pendent cam-plate, the back of which bears against the fixed bracket. At the lower end of this bar, is an oblong slot, through which the cam-shaft passes. This slot is of sufficient length to allow of the free vertical movement of the cam-plate. At each end of this slot, concentric with its centre, and projecting from the face of the cam-plate, are two circular inclines, one of which is seen at E^5 , commencing its rise, and terminating diametrically opposite, being half a revolution. One end of a steel pin abuts against the top of this incline, and passing in a horizontal direction through the catch-box D^2 , presses with its opposite end against the other half of the catch-box, holding it out of gear until acted upon. This half of

the catch-box slides freely upon a key, fixed on the cam-shaft. A spiral spring E^6 , one end of which presses against its boss, and the other against a stop-hoop, which is adjustable to regulate the tension of the spring E^6 , is fixed with a set-screw to the shaft. This cam-shaft next passes through the tubular cam-shaft D , to the back of the head-stock, where it has the wheel D^3 keyed upon it. When the end of the beam-lever E is pressed down, so that it turns on its fixed centre E^2 , moving its opposite end upwards, it carries the pendent cam-plate, with its circular incline, away from the steel pin; the new position allows the steel spring E^6 to act upon the catch-box, putting it into gear with the catch-box D^2 , which it carries round half a revolution, when the steel pin which is brought with it comes into contact with the second incline, puts it out of gear, and causes all motion to cease.

The tubular cam-shaft D runs in bearings, one at each end, projected from the frame side, and supports the last-mentioned shaft. The catch-box D^2 is keyed on one end, to give it motion. The cam 4, which acts on the lever 6, is also fast. The lever 6, passing upwards, extends to the catch-box e on the front roller c , and is carried by a stud in the frame, the centre of which is seen in the plan. The helical spring 7 is attached to this lever, and thereby holds the catch-box in gear. The partial revolution of the cam-shaft D is effected by the revolving bevel-wheel b , fixed on the boss of the loose-pulley B , on the first-motion shaft, which gears into another wheel b^1 , keyed on the top of the upright shaft F , which passes down to the scroll-shaft. Another bevel-wheel b^2 on the same vertical shaft gears into the large backing-off bevel-wheel b^3 , shown by dotted lines in the drawing, cast in one piece with the spur-wheel D^5 , and which runs loose on the journal of the main driving-shaft, and gears into the spur-wheel D^3 , on the end of the cam-shaft from which it receives motion. When the carriage arrives at the boundary of its stretch, the first movement of the cam-shaft D , actuated in the

manner explained, is to throw out of gear the catch-box c on the front roller-shaft, thus stopping the motion of the drawing-rollers and carriage. This is accomplished by the cams 4 and 5; the cam 4, coming round, presses against the projection on the lower end of the forked lever 6, working in the ring-groove in the projecting boss of the catch-box on the front roller-shaft. The cam 5 presses down one end of a beam-lever, the centre of which is seen at the opposite end, lifting the vertical bar, the top of which bears against the lower surface of the movable weight-lever c^6 , and disconnects the spur-wheel c^4 and the wheel c^5 , thus stopping the carriage.

The next operation is stopping the motion of the spindles. This is effected by the worm d on the first-motion shaft, gearing with the worm-wheel d^1 on the end of a short shaft d^2 , which passes through the bracket, fixed to the headstock; the opposite end of this shaft carries a cam d^3 , which acts at the proper time upon the end of the catch d^4 , hooking on the end of the bracket. The opposite end of this catch is joined to the strap-lever d^5 , which carries the fork to guide the strap. When the catch d^4 is hooked on the bracket, it retains the strap on the fast-pulley A. As the shaft makes one revolution during each stretch of the carriage, the cam d^3 is so adjusted as to act at the proper time upon the catch d^4 , liberating it from the bracket, when a helical spring is made to act upon the strap-lever d^5 , shifting the strap on to the loose-pulley B, thus stopping the spindle.

The next movement is that of backing-off. The lower end of the strap-lever hinges on a stud, fixed in the frame side, and, at this point, it branches off for a short distance, in a horizontal direction, towards the back of the frame, passing under a short projection from the backing-off lever d^6 . This projection rests upon the branch of the strap-lever; its office is to prevent a shock when putting the backing-off cones into gear as the strap leaves the fast-pulley. The backing-off lever oscillates on a stud

fixed in the frame. On the upward branch of the lever is a loose stud d' , which is secured to one end of a screwed rod, by means of two nuts, so as to be adjustable; the other end is attached, by means of a small stud, to one end of the horizontal lever d^3 , the middle portion of which fits the ring-groove on the boss of the conical friction-pulley, by means of which the latter is brought into frictional contact with the internal cone of the backing-off wheel b^3 , on the main driving-shaft, and is thus made to revolve in an opposite direction to the main driving-shaft, by the bevel-wheel, on the boss of the loose-pulley B, as before shown. Thus, when the friction-cones are brought into contact, combined with the motion of the pulley A^1 and the main driving-shaft, the change reverses the revolution of the spindles.

The depression of the faller-wire follows next. As soon as the backing-off commences, the ratchet-wheel j , which is keyed fast on the tin roller-shaft, is carried round with it. On the boss of this wheel, a ring-groove is turned, which is clipped by a bent spring j^1 , and the latter being carried round with it by frictional contact, its free end bears against the tail of a catch r , pressing it into gear with the ratchet-wheel j , which carries the last-named catch and its stud with it. This stud is fixed in the disc 3, which runs loose on the tin roller-shaft J . The boss of the disc is formed into a spiral groove, increasing in diameter as it approaches the flange. A chain j^4 is attached to this boss, and, winding round the spiral groove, passes horizontally towards the front of the carriage, partially round a flanged carrier-pulley, fixed on the top end of the lever p^5 , then up to and over a short bent lever p^3 , and is fixed on the faller-shaft p , being attached by means of a screw and wing nut, to adjust its length. This short lever pulls down the faller-wire to the apex of the cop. A lever p^1 is fixed on the faller, and, at its free end, is a stud, on which hangs the pendent bar p^2 . By the time the faller-wire s has attained the level of the

points of the cops in process of formation, the foot of the pendent bar is drawn upon the top of the slide, with its anti-friction bowl resting on the cop-shaper R. A stud is fixed in the pendent bar, to which the adjustable rod p^4 is connected, the other end being attached to the upper extremity of a short lever, placed just within the carriage. The opposite end of this lever is connected with a short shaft, at the extremity of which is fixed another lever p^5 , which passes downwards beneath the carriage. The free end of this lever is formed into a double or forked incline, sufficiently wide to fit the anti-friction pulley p^6 , which runs loose on a stud, fixed into the end of the lever p^7 . This fork presses down the friction-pulley, which carries with it the lever p^7 , the lower end of which is secured to the end of a short shaft, passing through a bracket, fixed to the lower portion of the frame. On the opposite end of this shaft, is fixed the boss of the lever p^8 , to which, at its lower extremity, is secured a stud; to this stud is attached one end of a long rod p^9 , which passes to the back of the headstock. Near to its extremity, is a stop-hoop, against which one end of a helical spring p^{10} abuts, the opposite end pressing against the lower end of the backing-off lever d^6 , where the rod passes freely through, compressing the spiral spring p^{10} . At its extremity, is fixed a second stop-hoop, which is fixed on the rod with set screws, being adjustable. The office of this stop-hoop is to disconnect the backing-off cones. The inward movement of the pendent bar stops the further descent of the faller-wire, and locks the faller to the shaper. The chain j^4 , being still in tension, draws the chain-pulley inwards; acting upon the upper end of the lever p^5 , and upon the lower end of the lever p^7 , move the long rod p^9 and stop-hoop p^{11} , carrying with them the backing-off lever d^6 , which puts out of contact the conical friction-pulley, when the backing-off ceases.

The drawing-in of the carriage is accomplished as follows:—On the upright shaft R, at the back of the

headstock, is a cone friction-pulley F^1 , one half of which slides on a key, fixed in the shaft; on its boss is a ring-groove. The other half runs loose upon the shaft, and, keyed upon its boss, is a bevel-wheel, which gears into a similar wheel on the scroll-shaft F^2 , which extends for some distance on each side of the headstock. Two scrolls are fixed on this shaft, one of which is shown at F^3 . A stout rope h , made fast to the boss, is then wound round the scroll attached by its end to the carriage, and thus pulls it in. A second rope is attached to the other end of the scroll, and is wound round in an opposite direction, passing off at the under side, and along the floor to the front of the headstock, where it passes over a carrier-pulley, fixed to the frame, and then back to the front of the carriage to which it is attached. At the lower extremity of the lever p^5 is fixed a stud, carrying an anti-friction bowl, on which the lever l rests while the backing-off is in progress; the boss of this is attached to the shaft l^1 , which passes along the floor to the back of the headstock. On this, is a second lever, having at its free end a fixed stud, on which is placed one end of a vertical rod l^2 , which is attached to the forked lever l^3 , the free end of which works in the ring-groove, on the boss of the loose half of the frictional cone-pulley F^1 , holding it out of contact. When the lever p^5 drops down, taking with it the lever l , it allows its shaft to rock, which causes the lever at the back end of the shaft to fall, bringing the cone friction-pulleys into contact, which gives motion to the bevel-wheels and scroll-shaft, and "puts up," or draws in the carriage.

The following are the details of the winding arrangement. At the moment that the cone-friction is in gear, the mitre-wheel G on the back shaft H , gears into the mitre-wheel G^1 on the side shaft G^2 . At the opposite extremity of the shaft, is a second pair of mitre-wheels, giving motion to the shaft G^3 , on the other end of which is keyed the spur-pinion I , gearing into the spur quadrant-wheel i^1 , which forms a portion of the radial arm i^1 , oscillating on a

stud fixed in the frame. A coarse-threaded screw t is mounted upon this arm, and on it is fitted a nut t , free to move up and down. To this nut, is attached a chain i , which, passing down, is wound upon the chain-drum i^1 , and made fast. The chain-drum i^1 is cast in one piece with the spur-wheel i^2 , and keyed on a short shaft, gearing into a spur-pinion i^3 on the boss of the disc i^4 , which runs loose on the tin roller-shaft j . A stud is fixed in the disc, which bears a catch i^5 , that takes hold of the teeth in the ratchet-wheel i^6 , fixed on the tin roller-shaft j . A bent spring clips into the ring-groove, in the end of the journal i^7 , and its free end rests on the small catch i^3 , thus completing the connection between the quadrant and the tin-roller, by means of which the yarn is wound upon the spindles.

When the backing-off is completed, and the faller-wire is down at the apex of the cop, the anti-friction bowl at the foot of the pendent bar p^2 is resting on the lower part of the short incline, at the front of the shaper R . As the carriage, on running in, commences to wind the yarn on the cop, the bowl ascends the incline, further depressing the faller-wire to the base of the upper cone. The action of the parts is to uncoil the chain from the winding barrel, which give motion, through the spur and ratchet-wheels, to the tin rollers, and thence to the spindles. The quadrant moves round its centre $\frac{1}{4}$ rev., and gives less chain, which increases the speed of the spindles, as the threads approach the apex of the cone of the cops.

When the building of the cop commences, the above-mentioned nut stands at the bottom of the screw, at the centre of oscillation. On the extremity of this screw, is a bevel-wheel T^1 , gearing into a similar wheel on the boss of a spiral wheel T^2 , running on a fixed stud. This spiral wheel gears into a second spiral wheel T^3 , on the shaft T^4 ; on the same shaft, is fixed the spiral roller T^5 . At this point the bowl begins to descend the longer incline of the shaper, which allows the faller-wire gradually to rise, guiding the thread to the apex of the cone of the cop, as the spindle

winds it on. For a short distance, at both ends of the shaft T^4 , is cut a screw-thread, which passes through a fixed nut bearing the shaft up. As the latter turns round, the spiral roller is taken towards the back, which gives less motion to the nut in the radial arm; this continues till the bottom of the cop is completed, when the spiral roller passes out of range, and its action ceases.

By means of this arrangement, when the yarn becomes too tight in winding on, the counter-faller o is depressed; a lever under the carriage, which is attached to the counter-faller by a chain, is lowered until it comes into contact with the spiral roller, to which it gives motion; by this means, the screw in the radial arm is turned round, working the nut upwards, until the yarn is slackened so much as to permit the counter-faller to rise, and to disengage the lever from the spiral grooves in the roller.

When the winding of the yarn upon the spindle is completed, and the carriage arrives at the drawing rollers, the fallers are disengaged by the pendent bar striking a fixed stop in the frame, pushing it outwards, and disengaging it from the slide, when the fallers rise by the action of their springs. When the carriage has been put up, and has arrived within a few inches of the roller beam, the faller-shaft comes into contact with the incline E^2 , pressing down the end of the long beam lever E , and forcing the pendent bar, with its circular incline, away from the steel pin, which allows the catch-box D^2 to turn the cam-shaft $\frac{1}{2}$ rev. when it puts the strap upon the fast-pulley, and all the other motions into their original positions, where they are ready to recommence spinning.

The operation of this complex arrangement of shafts, wheels, levers, pulleys, ropes, and springs, may be briefly recapitulated as follows:—The creel having been supplied with bobbins containing rovings, the ends of the latter are passed through small guide-wires, and between the three pairs of drawing-rollers c . The function of the back pair—that first taking hold of the roving—is simply to draw

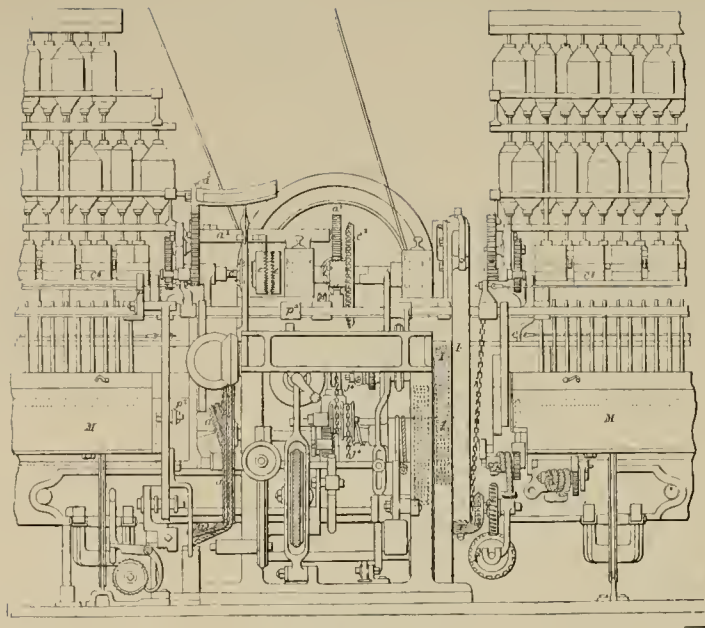


Fig. 62. Mule Headstock. Front elevation.

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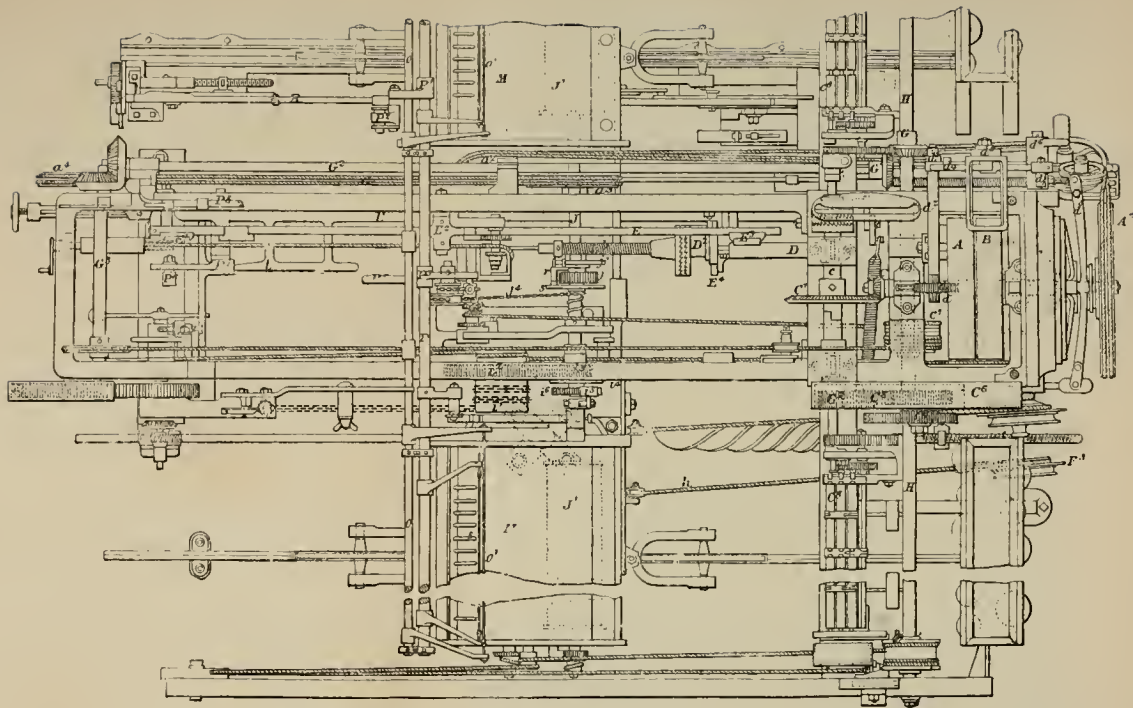


Fig. 63. Male Headstock. Plan, showing part of carriages on each side.

To face page 240.

the latter from the bobbin, and deliver it to the next pair. The motion of the middle pair is slightly quicker than the first, but only sufficiently so to keep the roving uniformly tense, in order that when delivered to the next, or front pair, running much more quickly, the "drawing," or attenuation of the roving may be equal throughout. Connection is then established between the attenuated rovings and the spindles. When the latter are bare, as in a new mule, the spindle-driving motion is put into gear, and the attendants wind upon each spindle a short length of yarn from a cop held in the hand. This done, the drawing-roller motion is placed in gear, and the rollers soon present the attenuated roving in front, to which the threads on the spindles are then attached, by simply placing them in contact with the untwisted roving. The different parts of the machine are next simultaneously started, when the whole works in harmony together, the back rollers pulling the sliver from the bobbins, and passing it to the succeeding pairs, whose differential speeds attenuate it to the required degree of fineness. As it is delivered in front, the spindles, revolving at a rate of 6,000-9,000 rev. a minute, twist the hitherto loose fibres together, thus forming a thread. Whilst this is going on, the spindle carriage is being drawn away from the rollers, at a pace very slightly exceeding the rate at which the roving is coming forth. This is called the "gain" of the carriage, its purpose being to eliminate all irregularities in the fineness of the thread. Should a thick place in the roving come through the rollers, it would resist the efforts of the spindle to twist it; and, if passed in this condition, it would seriously deteriorate the quality of the yarn, and impede subsequent operations. As, however, the twist, spreading itself over the level thread, gives firmness to this portion, the thick and untwisted part yields to the draught of the spindle, and, as it approaches the tenuity of the remainder, it receives the twist it had hitherto refused to take. The carriage, which is borne upon wheels,

continues its outward progress, until it reaches the extremity of its traverse, which is 63 inches from the roller beam, when the revolution of the spindles ceases, the drawing rollers stop, and the backing-off commences. This process is the unwinding of the several turns of the yarn, extending from the top of the cop in process of formation to the summit of the spindle. As this proceeds, the faller-wire, which is placed over and guides the threads upon the cop, is depressed ; the counter-faller at the same time rising, the slack unwound from the spindles is taken up, and the threads are prevented from running into snarls. When the backing-off is completed, the carriage commences to run inwards—that is, towards the roller-beam—the spindles winding on the yarn at a uniform rate, but by means of a varying speed in their revolution, as the faller is guiding the thread upon the larger or smaller diameter of the cone of the cop. Immediately the winding is finished, the depressed faller rises, the counter-faller is put down, and the former actions recommence in the order described, and are repeated until the “set” is completed—that is, the cops on each spindle are perfectly formed. In modern mules, when the set is finished, a stop-motion paralyzes every action of the machine, rendering it necessary to “doff,” or strip the spindles, and to commence anew. Doffing is performed by the attendants raising the cops partially up the spindles, whilst the carriage is out ; then depressing the faller, so far as to guide the threads upon the bare spindle below. A few turns are wound on, to fix the threads to the spindles for a new set, and then the cops are removed, being collected into cans or baskets, and subsequently delivered to the warehouse. The remainder of the “draw” or “stretch,” as the length of spun yarn is called when the carriage is out, is then wound upon the spindles by the carriage being run up to the roller beam. Work then commences anew.

This description of the operation of the parts composing that complex portion of the mule known as the headstock,

and which we may observe in passing is based upon the mule as constructed by Messrs. Curtis, Sons, and Co. of Manchester, does not show the number and intricacy of the problems it was necessary to solve before satisfactory results were attained. In view of the desirability of securing a fuller comprehension of these, and the means by which they were reached, it will be useful to enter into a little detail regarding them.

It has been shown that drawing rollers are common to all spinning frames, whether of the continuous or intermittent class; the latter differ from the former only in the means by which they are operated and their intermittent action secured. The drawing out of the carriage from the roller beam is the first distinctive action of the mule. This, as pointed out in connection with the jenny and Crompton's mule, was at first dependent upon the strength of the spinner, and its perfect manipulation upon his care and skill. The substitution of mechanism for performing this task was one of the earliest improvements. Until the invention of this "drawing-out apparatus," there was a limit to the elongation of the carriage, and consequently to the increase in the number of spindles. A difficulty encountered by the earlier inventors was to get the carriage to advance from the roller beam in a parallel line, when it was extended beyond a length that now would be regarded as exceedingly short. This drawing-out apparatus, the invention and operation of which has already been described, almost perfectly obviated that trouble for a time, but only for a time. Enlargements were carried so far, and speed increased to such a degree that an amount of vibration and unsteadiness, seriously detrimental to good work, was induced. This has again been obviated by the introduction of a "middle drawing-out apparatus," which consists of two additional scrolls placed on the back shaft, one in the middle of each half of the carriage. These scrolls are operated precisely as the others, except that the bands for convenience are made to pass under the carriage. The

carriage is thus governed at five points in its length; the centre, the middle of each half, and the extremities. By this change the carriage in coming out is again brought perfectly under control, and the tendency for each half to bend inwards at the centre forming a slightly concave line, is corrected, whilst the vibration resulting, when it is put up, is more quickly checked. It is largely owing to this that the high speeds now in vogue in our principal mills are rendered possible.

A similar difficulty was also formerly experienced in returning the carriage to the roller beam, when a stretch had been completed. The carriage was drawn in from the headstock which is its centre, and as its length was increased it was found that it could not be kept parallel when being returned home. This was obviated for a time by the invention of "the squaring-band," which was found to be a great improvement, though it left much to be desired. A successful endeavour was therefore made to obtain more power for, and a steadier return of, the carriage, which was accomplished by effecting a connection between the drawing-out or back shaft, and the taking-in shaft, which, by means of extra scrolls and bands, is thus converted into a taking-in as well as a drawing-out shaft. By this addition to its first function, the traverse of the carriage is rendered much more steady, the controlling bands being now six instead of two, as in former times.

The development of the faller wire has already been traced from Hargreaves' jenny to Roberts' self-acting mule, in which it assumed a form leaving little to be done by subsequent inventors, save in perfecting its details. In this respect much has since been accomplished, and it is doubtful whether any further advance can easily be made. The faller wire motion as extensively in use at the present time, and which differs only in small details in the mules of different makers, is described and illustrated as made by Messrs. Platt Bros. and Company, of Oldham, in a paper read before the Institution of Mechanical Engineers,

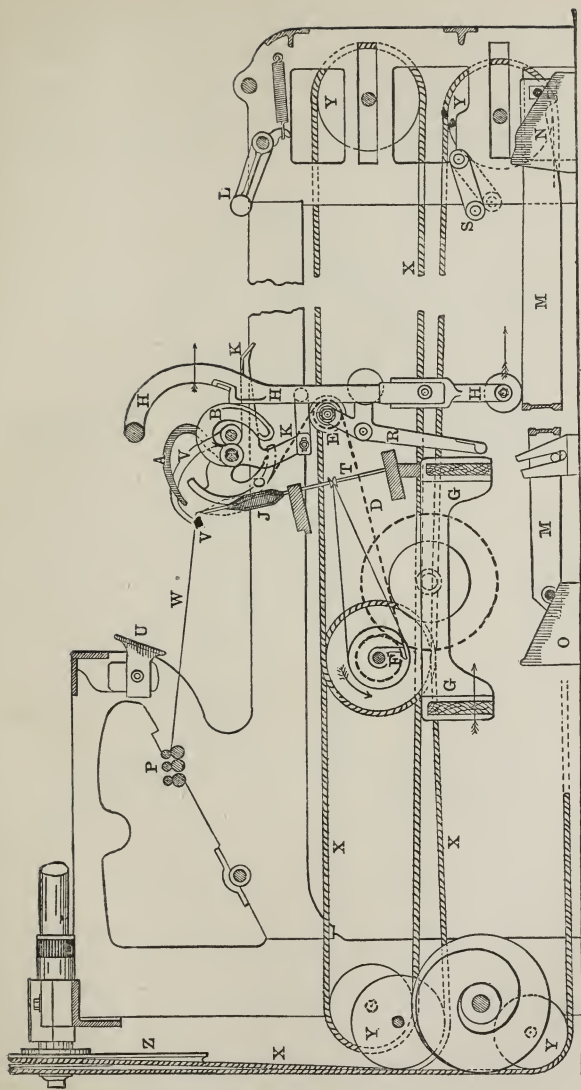


Fig. 64. Faller motion. Carriage running out spinning threads.

by the late Mr. John Platt, on "Machinery for Preparing and Spinning Cotton." Figs. 64, 65, 66, 67, show the details, and the following is the accompanying description, which permission has kindly been granted the writer to reproduce. Speaking of the faller-wire arrangement, Mr. Platt says :—

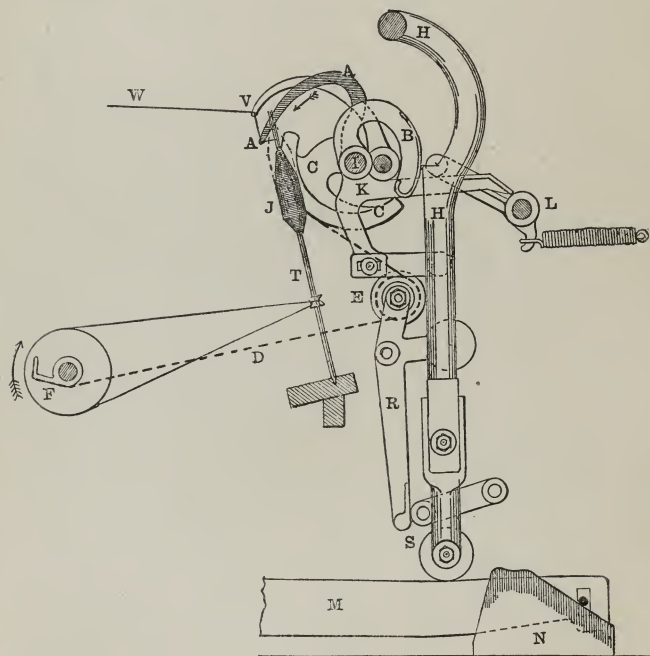


Fig. 65. Putting down Faller during backing-off.

"The top faller arm, A, is made of the sickle shape shown in the drawing, for the purpose of enabling it to put down the faller wire to the bottom of the cops, J, without the arm itself being required to pass down between the cops, so as to save room in the length of the mule. On the front of the faller shaft, I, is keyed the sector, C, and a chain, D, attached to it, passes round the pulley, E, to a snail, F, upon the shaft of the

tin roller, which by a series of bands drives the row of spindles, *t*. The snail is geared to the tin roller by a ratchet clutch, having its teeth set so as to engage only when the tin roller is driven the reverse way for backing off, as shown by the arrow in Fig. 65. Whilst the tin roller is running forwards during the spinning, and again during the winding, in the direction shown

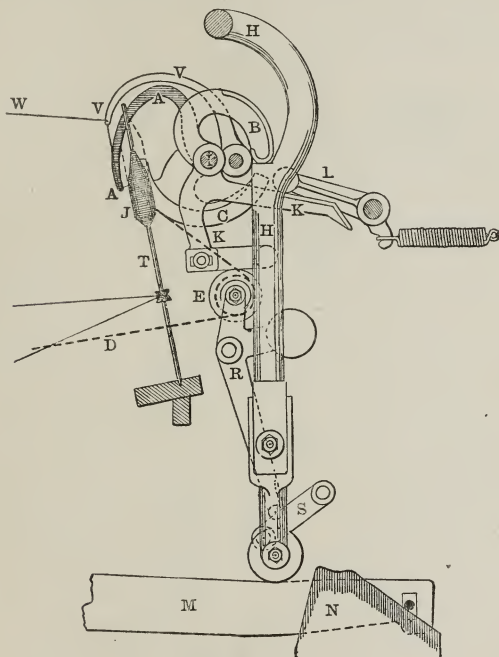


Fig. 66. Locking of Faller previous to winding.

by the arrow in Fig. 64, the snail, *f*, is not in action; but as soon as the carriage, *g*, of the mule has run out to the end of the stretch, as shown in Fig. 65, the tin roller is turned through part of a revolution in the reverse direction, as indicated by the arrow, sufficiently for unwinding the coils in backing off; the snail, *f*, then comes into action, and winds up the chain, *d*, thereby bringing the top faller wire, *a*, down upon the threads, *w*, and depress-

ing them towards the bottom of the cops. On the back of the faller shaft, *1*, is fixed the curved arm, *B*, against which bears the locking bar, *H*; and when the arm, *B*, is lifted by the depression of the faller, *A*, its extremity is caught by the recess in the bar, *H*, which is thrown forwards by the bell-crank lever, *K*, as shown

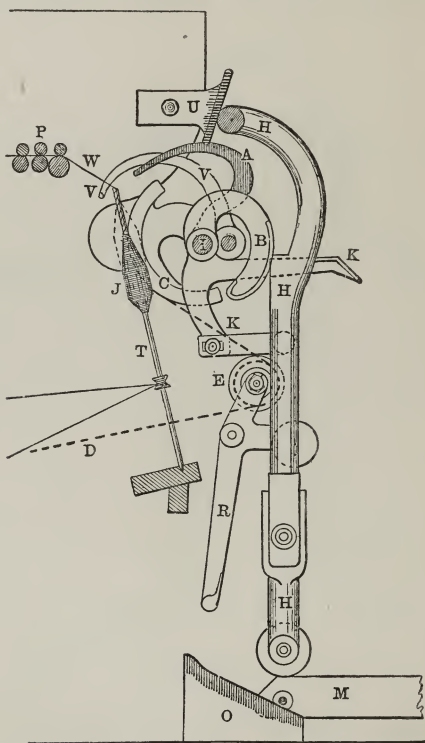


Fig. 67. Unlocking Faller at the end of winding.

in Fig. 66; the tail of this lever having been brought by the outward traverse of the carriage, *G*, under the corresponding bell-crank, *L*, fixed in the end frame of the mule, has previously extended the spiral spring attached to the bell-crank, *L*, Fig. 65, the recoil of which throws the locking bar, *H*, forwards as soon as the arm, *B*, is sufficiently raised (Fig. 66). The pulley, *E*, is carried on a

rocking lever, **R**, the tail of which presses against the stop, **S**, in the end frame of the mule during the time that the chain, **D**, is depressing the faller (Fig. 65); but at the moment when the locking-bar, **H**, is thrown forwards to lock the faller-arm, **B**, the stop, **S**, is lowered, as shown in Fig. 66, clear of the tail of the lever, **R**, allowing the pulley, **E**, to yield to the further pull of the chain, **D**, until the reverse motion of the tin roller in backing-off is stopped; by this means the snail, **F** (Fig. 65), is prevented from depressing the faller wire, **A**, beyond the required distance down the height of the cop.

“The faller being thus locked, the carriage, **C**, begins to run in the opposite direction to that indicated by the arrows in Fig. 64; and while the spindles wind up the threads on the cops, the faller wire is gradually allowed to rise by the locking-bar, **H**, running down the inclined coping rail, **M**, the curved arm, **B**, being kept constantly pressed home in the notch of the locking-bar by a counter-balance weight or spring acting on the back of the faller shaft, **I**, to raise the faller, **A**. The length of the stretch or run-in of the carriage, **G**, is 63 inches, which is therefore the length of the thread to be wound upon the cop, **J**, at each time of winding; and this whole length of 63 inches of spun thread is wound upon the cop during each stroke of the faller wire.

“The mode of building up the cop in successive stages is shown in Fig. 68, and in order to allow for the increasing diameter of the cop, the successive layers of thread are wound upon it in more open coils as the size increases, as indicated by the dotted lines, which is effected by gradually increasing the range of the faller wire; at the same time the ends of the cop are made of the conical form shown in the drawing. The length of the range or “chase” of the faller wire at the commencement of the cop upon the bare spindles is only from **A** to **B**, but this is gradually increased until the cop has attained its full diameter at **C**, **C**, when the length of range is from **C** to **D**; after which it is slightly diminished again to the length, **E**, **F**, in finishing the cop. For the purpose of obtaining the requisite motion of the faller wire for giving these successive shapes to the cop during the winding, the extremities of the coping rail, **M** (Fig. 64), are supported on the two sliding wedges, **N** and **O**, which are kept at an invariable distance apart by a connecting-rod. In commencing

the winding of a set of cops upon the bare spindles, as shown at A, B (Fig. 68), the copping rail is set at the top of the wedges, and is at its smallest inclination; and after each successive layer has been wound on, the two wedges are slid from under the

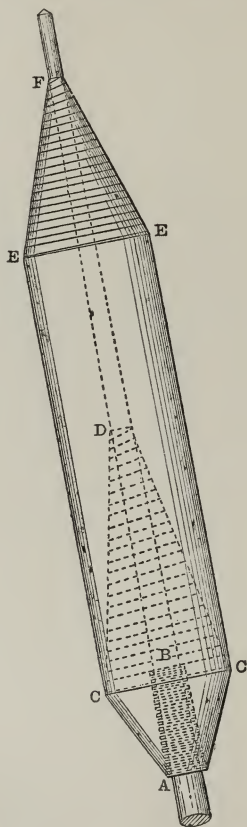


Fig. 68. Mode of building up cops; half full size.

rail by a traversing screw worked by a ratchet wheel, which is advanced one or more teeth during each run out of the carriage, G (Fig. 64). By this means the copping rail, M, is gradually lowered at both ends, and, at the same time, its inclination is in-

creased by the outer wedge, *n*, being made with a rather smaller angle at the top than the inner wedge, *o*, for the purpose of forming the cop with a more gradual taper at the top than at the bottom, as shown in Fig. 68. This increase of inclination continues until the cop has attained its full diameter, *c, c*, and has assumed the shape, *A, c, d*; after which the inclination slightly decreases again until the cop is completed to the finished shape, *A, c, e, f*, by the latter part of the outer wedge, *n*, being made slightly steeper than the corresponding portion of the inner wedge, *o*, as shown in Fig. 64. The inner end of the copping rail being the lowest, the winding of each stretch leaves off at the top; and at the commencement of winding each stretch the faller wire puts down the thread to the point at which the winding of the new layer is to be started, about three coils being wound on during the descent of the faller, as indicated by the spiral dotted line from *f* to *e* in Fig. 69, and the remainder during the rise of the faller. When the spindles arrive at the rollers, *p*, as shown in Fig. 67, having wound up the 63 inches stretch of threads, the stop, *u*, pushes back the locking bar, *h*, thereby releasing the faller, *a*, which immediately rises clear of the threads, *w*.

The counter faller wire is carried by the arm, *v*, from a second shaft behind the top faller shaft, *i*, and during the winding it bears up constantly against the under side of the threads, *w*, as shown in Figs. 65 and 66, with a slight pressure from a counter-balance weight or spring acting on the shaft, so as to ensure keeping the threads in proper tension; during the spinning the counter faller is held up just beneath the threads, but without touching them, as shown in Fig. 64. The arm, *v*, of the counter faller is curved, as shown in the drawing, so as to reach over the shaft, *i*, of the top faller, and also to avoid passing down between the cops; and the curved arm, *b*, on the back of the top-faller shaft, *i*, is shaped so as to clear the shaft of the counter faller. The height of the counter faller wire is employed as a means of regulating the speed of the spindles in winding in the manner afterwards explained, so as to avoid the occurrence of any slack in the threads."

The mechanism of the faller wire having been thus described, the next portion for detailed notice is the arrange-

ment for backing off. The following is the description and plan (Fig. 70) of the arrangement of the main driving or rim shaft of the headstock, as given in the same paper.

“The rim shaft, A, carries the large rim wheel, z, or double-

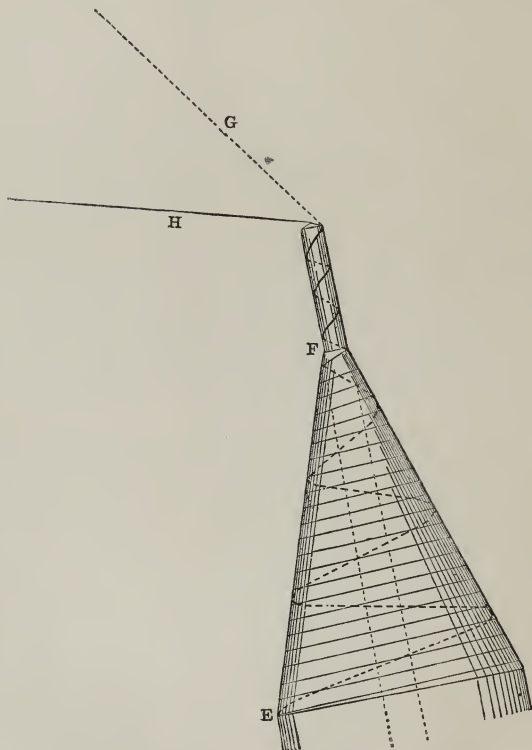


Fig. 69. Extreme inclination of thread to spindle in spinning.

grooved pulley, driving the whole of the mule spindles by the endless cords, x, x (Fig. 64), passing round the pulleys, y, y. On the boss of the loose pulley, B, is a pinion, c, which, through a train of intermediate wheels, d, d, drives in the reverse direction, and at the required slower speed, the spur wheel and

friction cone, *E*, also running loose upon the shaft, *A*, and sliding longitudinally upon it. This friction cone engages in a corresponding hollow cone inside the fast pulley, *F*, to the loose pulley, *B*, for the purpose of backing off, the friction cone is also brought up against the fast pulley, thereby first arresting by friction the forward motion of the driving-shaft, *A*, and then giving it the reverse motion for backing off."

The details of the winding quadrant for regulating the winding of the threads, by diminishing the speed of the

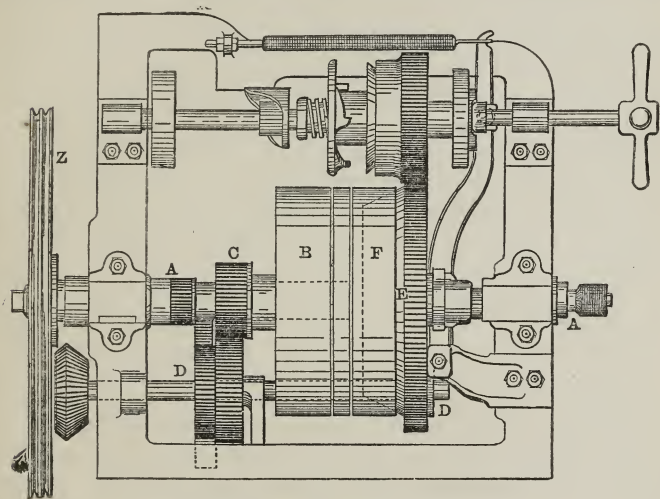


Fig. 70. Plan of backing-off motion.

spindles, in proportion to the increase of the diameter of the cops, is shown in Fig. 71. This arrangement, the invention of Richard Roberts, formed an important part of his self-acting mule, and has continued to the present time its distinguishing feature. Few, if any, mules of this class are ever made without it.

"The quadrant, *A*, turns upon a fixed centre, *c*, in the frame; and a pinion, *B*, gears into it, which is driven by a band and pulley, receiving motion from the traverse of the carriage, *G*, the

arrows indicating the direction of motion during the run-in of the carriage. The grooved arm, *D*, of the quadrant contains a double-threaded screw, by which the sliding nut, *E*, is traversed outwards from the centre of motion, *C*, towards the extremity of the arm, *D*. When the carriage is at the outer end of its stretch, the arm, *D*, stands inclined 12° outwards from the vertical, as shown by the dotted lines; and during the run-in of the carriage, it turns inwards through an arc of 90° . A chain, *F*, attached to the nut, *E*, is coiled round a drum, *H*, inside the carriage, *G*; and as the carriage recedes from the quadrant arm during the run-in, the chain thus causes the drum to rotate, and thereby drives the spindles, *T*, through the intervention of the tin roller, *I*, geared to the drum, *H*. At the commencement of a set of cops, the nut, *E*, is at the bottom of the quadrant arm, *D*, nearest to the centre of motion, *C*, as shown dotted; and the number of revolutions then given to the drum, *H*, by the uncoiling of the chain during the run-in of the carriage is nearly as many as if the end of the chain at the nut were held stationary, and is sufficient to wind up on the bare spindles the length of threads spun in one stretch."

"As the cops increase in diameter from their original size, *A*, *B*, to their full diameter, *C*, *C* (Fig. 68), the nut, *E*, is gradually advanced outwards along the quadrant-arm, *D* (Fig. 71), so as to increase its arc of motion, and thereby diminish the number of revolutions of the drum, *H*, and the speed of the spindles, *T*. This advance of the nut is obtained from the counter-faller, *V*, bearing against the underside of the threads, *W*, during the winding. The depression of the counter-faller towards the lower part of the cop, *J*, brings down the end of a governing lever upon a horizontal strap, which passes round a pulley, upon the headstock of the mule, and round another on the centre shaft, *C*, of the quadrant; and on the shaft is a bevel pinion gearing into a second bevel pinion on the end of the double-threaded traversing screw in the arm, *D*; so that when the governing lever is depressed upon the strap of the counter-faller, the forward motion of the lever, as the carriage runs in, drags the strap along with it by friction, and turns the shaft, *C*, forwards, sliding the nut, *E*, outwards towards the circumference of the quadrant. At the moment when the backing-off motion has ceased, and the carriage

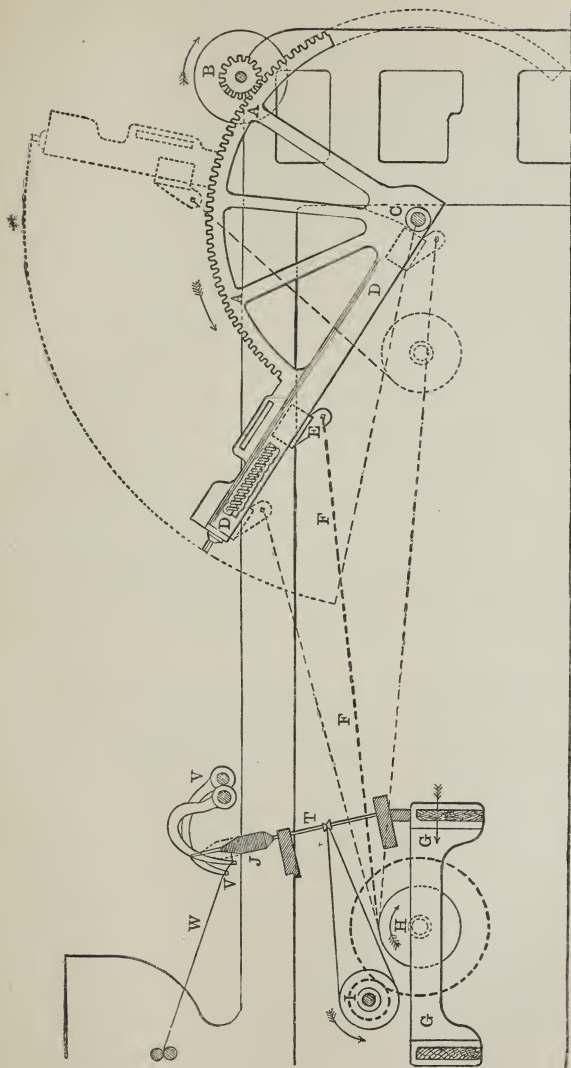


Fig. 71. Roberts' Quadrant for regulating speed of winding. Carriage running in and spindles winding up threads.

begins to run in for winding up the stretch of the thread spun, as shown in Fig. 66, the counter-faller wire, *v*, is at its highest working position, compensating for the additional length of thread that has been uncoiled from the top of the spindle in backing off after the spinning of the stretch was completed. The nut, *e*, however (Fig. 71), is still at the same distance from the centre, *c*, of the quadrant, as it was at the conclusion of winding the previous stretch; and, therefore, as the diameter of the cop is now greater by winding the last new layer of thread outside the previous one, the winding of the new stretch commences rather too fast, and begins at once to take up the length of thread given out in the backing off. The counter-faller, *v*, is thus depressed, and, by means of the governing lever, slides the nut, *e*, further out from the centre, *c*, until the speed of the winding is sufficiently diminished to allow the counter-faller to rise again high enough for lifting the governing lever off the strap. It will be seen that, in consequence of the arm, *d*, describing the quadrant of a circle, the horizontal motion of the nut, *e*, in the winding of each stretch is greatest at the commencement of the winding, and gradually diminishes as the carriage runs in; and the effect of this is that the speed of the winding is gradually increased towards the end of each stretch. By this means the threads are wound uniformly upon the cops, with an equal degree of tightness throughout."

Such was the self-acting mule until within a few years ago. It was not quite perfect, inasmuch as though performing the principal operations automatically, and with a considerable degree of accuracy, it was still dependent upon the skill of the superintending operative for the performance of some of its minor operations. Several of those that were automatically performed, were also imperfect in more than one respect. The governing arrangement of the quadrant nut was neither sufficiently sensitive nor reliable for the performance of good work. In both these respects it has been greatly improved, and has been rendered adaptable for a much wider range of work than previously. The backing-off motion was also defective in its arrangement, and this often caused "snarls" or kinks to

be produced in the yarn, a fault which it was highly desirable should be avoided if possible, as it seriously depreciated the value of the yarn. This has been accomplished. A defect in the winding motion, arising from the peculiar form of the spindle, was a long-standing trouble to spinners, and an almost insurmountable difficulty to inventors. The quadrant winding apparatus was constructed to form a cop on a spindle equal in its dimensions from the bottom to the top, and on which the winding throughout would be equally good. But in this construction the important fact was ignored—probably at the time regarded as too small for notice—that the spindle is not of equal thickness throughout its length, but is tapered, the thickest part being the base. If the winding was arranged correctly for the spindle at the base of the cop, there was a steadily increasing departure from this point during its building up, so that towards its completion the winding became so slack as to lead to the entanglement, “halching” it was called, of the thread at the “nose” or apex of the cop, which caused a great amount of waste in the subsequent process of winding the yarn upon bobbins, or in reeling it for bundling. This difficulty, too, has been overcome, and the aggregate result is a great improvement in the quality of the work produced from the mule as now made in the best form. As these involve some of the nicest problems yet encountered in connection with the mule, a description of the means by which they have been solved will not fail to be instructive. In giving this I cannot do better than avail myself of the description of the means adopted by Messrs. Platt Bros. and Co., Oldham. This was given in detail in a paper by Mr. Eli Spencer, read before the Institution of Mechanical Engineers, previously mentioned, in which he reviewed the progress that had taken place since the subject was brought under notice in the paper by Mr. Platt, and from which the preceding quotations have been made. This was illustrated by drawings, which permission has been given to reproduce.

“The backing-off motion has been perfected, its operation being regulated automatically to suit the position of the cops at every stage of their progress, from the commencement of winding to the completed full cop. Formerly this apparatus was imperfectly manipulated by the minder. The copping apparatus is now used as the controlling agent for regulating this motion. This is shown in Fig. 72. It is made with a separate front incline, *D*, which is loose, and is governed by an additional front copping plate, *E*. Formerly only two points in the copping rail, *A*, were capable of being adjusted to the exact positions required; whereas by the use of the loose incline, *D*, all the positions are now regulated. The advantage gained by this latter arrangement is the power of regulating the precise position of the faller wire when the faller is locked—a very important consideration. In the hand mule, when the spindle had depressed the faller wire to the proper position for winding, and uncoiled the exact amount of yarn from the bare spindles, he arrested the operation of backing-off and commenced the winding on. In the self-acting mule with the copping rail in one solid piece, this important object could not be attained. The amount of inclination in the front was determined by the conditions required to commence the cop on the bare spindles. At the commencement it was very important to keep the ‘chase’ of the cop, or the height of the cone, as shown at *A*, *B*, Fig. 68, as short as possible, in order to prevent waste in unwinding in the subsequent processes. When the copping rail was set at the commencement of the cop, the position of the faller wire was determined, and set to suit the requirements of the operation; but as soon as the winding part of the copping rail assumed the more inclined position to enable it to wind a longer chase, then the front incline assumed a less inclined position, leaving the faller wire at the time of the faller locking in a worse position at each successive draw, until the chase had attained its maximum at *C*, *D*, Fig. 68, and had begun to be gradually shortened again. This was in reality a complete reversal of the practice of the hand-spinner’s operations. For many years this method was considered quite satisfactory, but the demand for longer cops, built more firmly, gave the impulse to the present improvement. The front incline being now made movable, its position can be regulated so that the operation will

be an exact counterpart of the hand-spinner's work, when he made his best cop, and by the use of an apparatus for tightening the backing-off chain, in connection with the loose incline, *D*, on the coping rail, the amount of yarn uncoiled from the spindles is regulated to suit the position of the faller wire at the termination of the backing-off. When once set this apparatus needs no attention from the minder."

"As the coping motion has been previously explained, it is only necessary here to describe what relates to the loose incline shown in Fig. 72. The coping rail, *A, A*, rests at one end on the front coping plate, *C*. One end of the loose front incline, *D*, is jointed to the ridge of the coping rail by the pin, *F*, and its front end rests on the additional coping plate, *E*, which is fastened to the coping plate, *B*, in such a manner that it can be adjusted to suit the requirements of the loose incline, *D*. By varying the form and position of the additional coping plate, *E*, the loose incline, *D*, can be regulated to give any required results."

"The diagram shows the faller locking arrangements, with the lock at the bottom of the lever, *R* (Fig. 72), instead of as in the former arrangement at the top. The principle is the same in both systems, the alteration being made to suit the requirements of other parts of the head stock connected principally with what are technically called the 'changes.'"

The means by which the defects of the quadrant arising from the tapered form of the spindle, have been overcome, is an improvement in the backing-off-chain tightening motion. A little further explanation of why this is required may be desirable.

"When the carriage, *G* (Fig. 72), is making its outward run, the front or winding faller wire is generally about $1\frac{1}{4}$ inch above the points of the spindles, *S*. This is also the position of the parts in ordinary mules, immediately before the operation of backing-off the spiral of yarn that is coiled upon the bare spindles above the top of the cop. As is well understood, the reversal of the tin roller causes it to uncoil this yarn from the spindles and also brings into action the parts which pull the faller wire down. In all cases the spindles begin to uncoil before the faller wire

begins to move, because the tin roller must make some little movement before the backing-off click or pawl can take hold of the ratchet wheel. In addition to this the spindles continue to uncoil the yarn during the time the faller wire is moving from its position above the spindle points, until it touches the yarn. From this it will be seen that a considerable length of yarn will be uncoiled from the spindles before the faller wire can overtake the yarn. The spindles thus have the start very considerably, and at the completion of a set of cops this loss of motion of the faller wire produces the worst results. In the case of a cop with its nose or point only $\frac{3}{4}$ inch from the spindle points, the loss is nearly one-half the entire motion of the faller wire, which moves as far before it touches the yarn as it does after. To overcome this difficulty it is necessary to have the backing-off chain tight, so that it may act on the faller as early as possible; and the backing-off snail is made as large as possible and of the proper form, so that the faller wire may act on the yarn at the earliest moment.

“At the commencement of a set of cops, the conditions are very much more favourable; for, although the space actually passed through by the faller wire before it touches the yarn remains constant, it bears at the commencement a very much smaller proportion to the entire distance passed through by the wire before the faller locks, than it does at the completion of the set of cops. Consequently the backing-off chain has to be slack at the beginning of a set of cops, otherwise the speed of the faller wire would force the yarn down the spindles faster than it would uncoil, and would thereby break the thread. Hence the backing-off chain having been adjusted to the proper length for backing-off nicely at the commencement of the set of cops, it is desirable gradually to tighten or shorten it as the cop increases in length, until at the completion of the cop, the chain is almost tight. By this means the backing-off can be adjusted all through the set, so that it corresponds at every stage with the exact requirements of the case; the nose of the cop is preserved in a properly firm condition, and neither too much nor too little yarn is uncoiled. Next to winding the yarn properly on the cop, this is the most essential condition in making a good cop. Where the apparatus now to be described, which effects this automati-

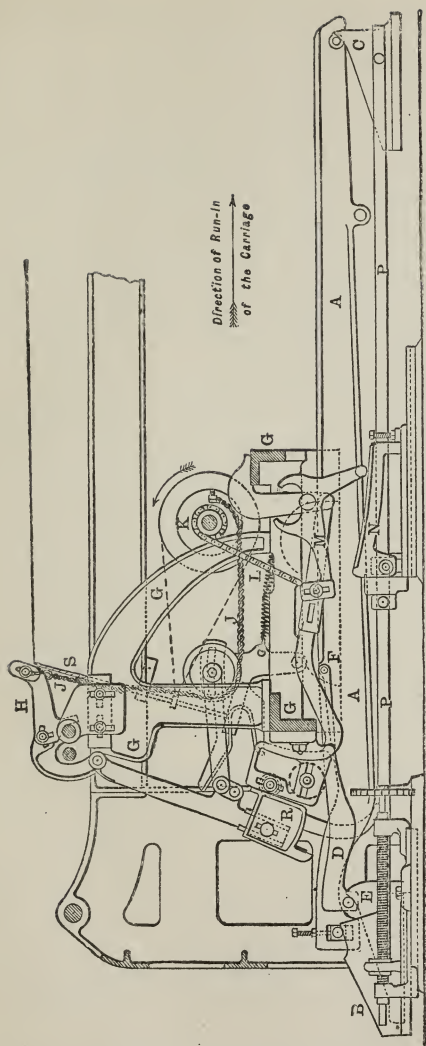


Fig. 72. Backing-off chain tightening motion.



cally, is at work, it is found that very much fewer noses or points of cops are 'halched' or entangled.

"Referring to Fig. 72, the winding faller shaft, *i*, has keyed upon it the backing-off finger, *h*; the backing-off chain, *j*, is fastened at one end to the finger, *h*, and, at the other end, to the backing-off snail, *k*, which is mounted with a ratchet clutch upon the tin roller shaft. The backing-off tightening-chain, *l*, has one end fastened to the boss of the snail, *k*, and the other end to the bell-crank lever, *m*, the tail of which is shown resting on an incline, *n*. This incline slides upon a plate fastened to the floor; and an arm upon the front end of the incline grips the copping plate connecting rod, *p*, by set screws, the incline, *n*, is caused to move backwards with the backward motion of the rod during the formation of the cop.

"In Fig. 72 are shown the positions of the carriage, *g*, and the various parts just previous to the time of the backing-off taking place at the commencement of a set of cops. The backing-off chain, *j*, having been adjusted to the proper length for backing off on the bare spindle, the copping plates, *b* and *c*, with the connecting rod, *p*, will gradually move inwards or backwards, in the direction of the arrow, as the cop progresses, and will carry the incline, *n*, with them in the same direction. This movement gradually brings the higher part of the incline, *n*, under the tail of the lever, *m*, causes it to turn in the direction of the arrow, and so pulls the chain, *l*, which, in turn, acting on the snail, *k*, takes up the slack of the backing-off chain, *j*. The incline, *n*, is so made that it can be varied to suit the particular requirements of various kinds of mules. The absolute amount of tightening depends upon the setting of the incline, or upon the differences of level between its two extremities; and the rate of tightening at different parts of the incline depends upon the form of its outline. By varying the form of the incline, the action on the chain can be varied to suit any circumstances. When once set, the apparatus needs no further attention. At the commencement of a new set of cops, the copping plates, *b*, *e*, *c*, are wound forwards again, into the position shown in Fig. 72, the incline, *n*, goes with them, and the backing-off chain, *j*, is restored to its normal slackness."

It has already been sufficiently explained, that Roberts'

quadrant winding apparatus admitted of no variation beyond the gradual outward traverse of the quadrant nut to suit the increasing diameter of the cop until the maximum was attained, after which no further modification took place. This, however, did not fully meet the requirements of the case, as no provision was made for the tapered form of the spindle. Had the spindle been uniform in its diameter, the quadrant in the form Roberts left it would have been comparatively perfect, but this was not so, and the increase of the length of the spindle that of late years has taken place, required to meet the demand for higher speeds and larger cops, has intensified the evil experienced. The diameter of the blade, or winding part of the spindle, has grown to $\frac{1}{3}$ inch in its largest part, whilst it tapers down to $\frac{1}{16}$ inch at the top. It will be seen from this that the speed, or rate of revolution, of the spindle, when "nosing" or winding on the bare portion of the spindle at the early part of a set will require to be very much less than when at the finish, and that the acceleration will require to be gradual throughout the set in order that the nose of the cop may be tightly and firmly wound throughout. This acceleration of speed, which usually takes place when the carriage in its inward run is closely approaching the roller beam, requires to be in a ratio exactly corresponding to the diminution of the diameter of the spindle. Also its commencement must be a little earlier with each succeeding draw, so that at the finish of a set it will commence five or six inches away from the termination of the inward run of the carriage. It is necessary that the time of its commencement should be nicely adjusted to the position of the faller wire, as should it begin too early the yarn will be rapidly wound upon a portion of the top cone of the cop that will take it up too fast, and so strain or break it, in either of which cases it will be greatly injured. In fact, yarn was injured in this manner until within a comparatively recent time. Many contrivances were designed for obtaining this necessary acceleration of the spindle's velocity, but they

almost all failed either in obtaining the right degree or in commencing at the right moment.

“The one most generally in use is that called the ‘Nose Peg.’ This peg, acting on the winding chain, *r* (Fig. 73), deflects it from a straight line into a bent line, causing additional chain to be uncoiled from the winding-on drum, *H*, and consequently increasing the velocity of the spindles. This, although an improvement, imparts but little acceleration; and the little it does begins too early—say, about 18 in. from the end of the inward run of the carriage. Various forms have been given to the peg, but all amount to the same thing in practice.”

Subsequently, in 1863, the nose-peg bracket was converted into a swing lever, which was mounted on the quadrant. Both this and the successive modifications of it, until the invention of the scroll-drum nosing motion (the description of which follows), were merely variations of means to deflect the winding-on chain. None of these, however, satisfactorily answered requirements. The quality desired, and which was essential to a perfect appliance, was a progressive acceleration of the revolution of the spindle in a ratio equivalent to the diminution of its diameter, so that a given length of thread should be wound upon a smaller circumference in the same time. The problem, in fact, was an inverse form of that encountered in the slubbing and roving frames, and which in those instances was solved by the differential motion of Holdsworth. The difficulty of solving the problem, however, was complicated by its requirement of an intermittent action of short duration. The last invention relating to this, and which seems to answer all needs, is the automatic nosing motion brought out by Messrs. Platts, and which consists of a scroll placed upon the end of the winding-on drum, *H* (Fig. 73). The following is a description from the paper previously referred to:—

“When the cop has attained its full diameter, *c, c*, Fig. 68, the scroll-drum, *H*, should be in the position shown in Fig. 74, on the

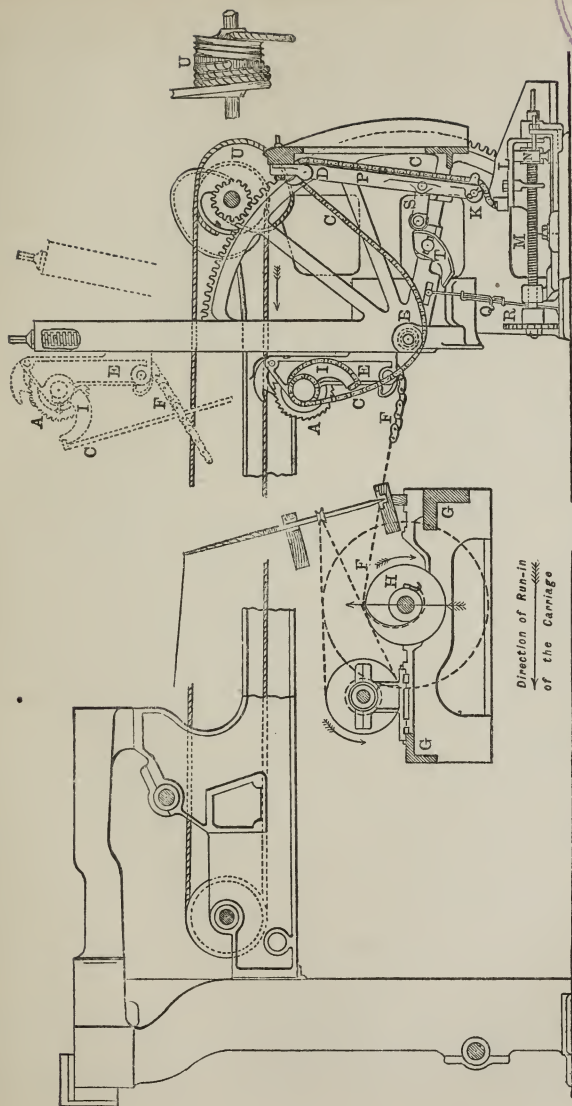


Fig. 73. Automatic nosing motion ; general arrangements.

completion of the inward run of the carriage, *g*. As the cop becomes gradually built up higher on the taper spindle, more winding chain ought to be uncoiled from the scroll, until, at the completion of the cop, the chain should be wholly uncoiled, as shown in Fig. 75. It will be understood that the velocity of the winding increases in the same ratio as the diameter decreases of the scroll, *h*, from which the chain is uncoiled. The amount of acceleration thus given depends on the quantity used of the scroll winding-drum, and the character of the acceleration on the form of the scroll end of the winding-drum. Its range of acceleration is very much greater than that of any other apparatus yet invented. Fig. 73 shows the position in which the parts should be placed to commence with. The quadrant is shown in the position in which it stands when the bowl is on the ridge of the coping rail. The carriage, *g*, is shown in the position, when it has made about 12 in. of its inward run. Fig. 77 shows the quadrant nut, *e*, with the parts on it in the same position as shown in Fig. 74—that is, when the cop bottom has just been completed. The carriage, *g* (Fig. 74), is shown close up to the back stops. The quadrant, *e*, is in its final or extreme outermost position for making the rest of the cop. The arrow across the winding-on drum, *h*, is in the same position as shown in Fig. 73—that is, the chain, *f*, has been uncoiled from the cylindrical part of the winding-on drum, until it is on the point of uncoiling from the scroll part. The arrow-head crosses the drum where the cylindrical concentric part ends and the scroll begins. Fig. 75 shows the position of the parts on the completion of a set of cops. It will be observed that the winding chain, *f*, is here uncoiling from the small end of the scroll, *h*.

“The end of the winding chain, *f* (Fig. 73), instead of being merely attached, as formerly, to the quadrant nut, *e*, is now wound upon the body of a ratchet wheel, *a*, on the shaft of which is also fixed a scroll, *i*. Another chain, *c*, coiling on this scroll, passes thence under and over the stationary pulleys, *b* and *d*, and under the swinging pulley, *k*, and its end is fastened to the sliding bracket, *l*, which slides on the shaper screw, *m*, of the coping motion. The pull of the chain, *c*, causes this sliding bracket, *l*, to press outwards against the front ring of the shaper frame, which carries the shaper screw, *m*. The shaper screw is

turned as usual by the ratchet wheel, *r*, which is moved through one tooth at each lift of the quadrant by the wire, *q*. The nut, *n*, travelling in towards *r*, along the shaper screw, comes into contact with an inner arm on the bracket, *L*, as shown in Fig. 74,

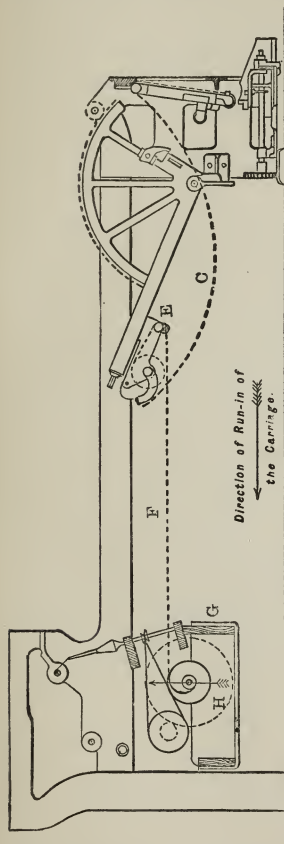


Fig. 74. Completion of cop bottom.

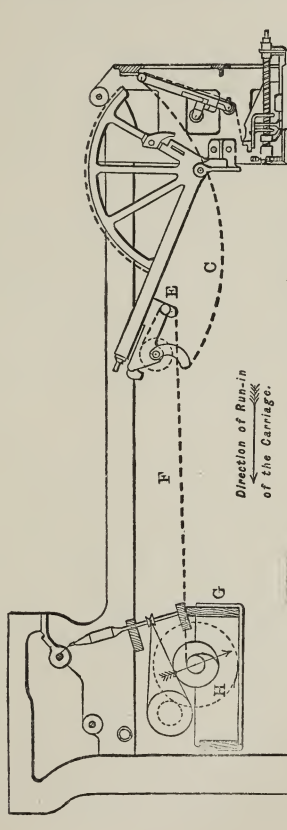


Fig. 75. Completion of cop.

and causes it to slide inwards with the inward movement of the nut, and so gradually pulls the chain, *c*, in the same direction. The inner arm on the bracket, *L*, is made adjustable for the purpose of regulating the time when the nut, *n*, of the shaper screw

shall come into contact with it. The swinging pulley, *κ*, is carried at the bottom extremity of the lever, *ρ*, suspended from the centre, *ν*; and on the lever is centered an arm, *σ*, free to turn upwards, but not downwards. A bracket, *τ*, upon the quadrant is capable of pushing outwards the lever, *ρ*, by means of the arm, *σ*, when the quadrant is rotating outwards. The steel end of the winding chain, *φ*, which goes into the quadrant nut, *ε*, is about 3 feet long. The remainder, or curb part of the chain, will therefore be shorter than usual, and does not enter into the quadrant nut at all, and thus escapes the wear it would otherwise incur in passing round the small anti-friction pulley at the bottom of the nut, *ε*."

"The parts being properly adjusted, the mode of working is as follows:—After the first stretch, the governor motion from time to time moves the quadrant nut, *ε*, further out from the centre of the quadrant, so as to adjust the winding to the increasing size of the cop. By this movement of the quadrant nut the slack in the chain, *c*, is soon taken up, and after the slack is taken up, the further outward movement of the quadrant nut causes the chain, *c*, to pull the bottom of the lever, *ρ*, inwards. On the return or outward run of the carriage, the bracket, *τ*, acting on the arm, *σ*, forces the lever, *ρ*, outwards again; and in so doing pulls a length of chain, *c*, from the scroll, *ι*, thereby causing it to turn on its axis and wind upon the ratchet wheel, *α*, a length of winding chain, *φ*, which would otherwise remain coiled upon the winding-on drum, *η*; the ratchet wheel is caught by one or other of two detent catches, which enter into its teeth. In consequence of the ratchet wheel in the quadrant nut thus taking up at intervals a length of winding chain about equal to the increasing distance of the nut from the quadrant centre, *ν*, the length of chain left coiled on the winding drum, *η*, at the end of each inward run of the carriage will remain nearly the same, until the cop has attained its full diameter, when the parts should be in the position shown in Fig. 74, the nut, *ε*, having then reached the farthest extremity of its travel along the quadrant arm. Till this stage, the sliding bracket, *λ* (Fig. 73), will still remain pressed outwards against the front ring of the shaper frame. About this time the nut, *κ*, on the shaper screw will come into contact with the sliding bracket

as in Fig. 74, and will gradually draw the bracket inwards, together with the chain, *c*, and lever, *p*; it will thus draw a further length of chain, *c*, from the scroll, *i*, wind up a further length of winding chain, *f*, upon the ratchet wheel, *A*, and cause the chain, *f*, now to unwind not only from the cylindrical, but also from a portion of the scroll part of the winding-on drum, *H*. The repetition of this action gradually brings more and more of the scroll part of the winding-on drum, *H*, into operation, until at the completion of the set of cops (Fig. 75), as much of the scroll part has been brought into action as the circumstances of the case require. By causing the nut, *N*, of the shaper screw to act sooner or later on the sliding bracket, *L*, a greater or less amount of the scroll on the winding-on drum, *H*, may be brought into use. By these arrangements, the winding can be accommodated to any form of spindles. On the completion of a set of cops, the scroll, *i*, on the quadrant nut, *E*, should be in the position shown by the dotted lines in Fig. 73, at the top extremity of the quadrant arm. Before beginning a fresh set of cops, the winding chain, *f*, must be uncoiled from the ratchet wheel, *A*, in the quadrant nut."

It will be obvious from this explanation, that this invention is an important one, doing much to remedy the evils springing from slack winding, arising from the configuration of the spindle. These were not confined to the entanglement or "halching" of the yarn on the nose of the cop, but also included the running of the yarn into snarls or kinks as before stated. These caused a further fault, as the "twist" in the fibres had a tendency to run together into these snarls, leaving other portions comparatively without, which were therefore rendered "soft;" that is, the fibres no longer being held together by the twist, had no coherence when subjected to even the slightest strain. The presence of these faults was a great drawback to the quality of any yarn. The automatic nosing motion, however, did not entirely obviate this defect, as a contributory to its production was found in another portion of the machine. In the same paper relating to this matter, the writer continuing says:—

“A further improvement in the winding motion has been effected by a change in the manner of engaging the click with the click-wheel on the shaft of the tin roller, *κ* (Fig. 76). Formerly the movement of the carriage, *G*, at the commencement

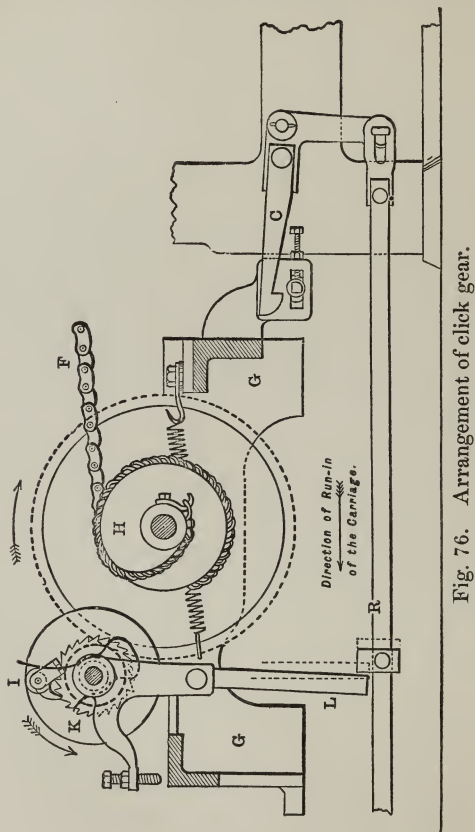


Fig. 76. Arrangement of click gear.

of its inward run, by means of the winding chain, *F*, drum, *H*, and spur-wheel and pinion, caused the loose click-plate carrying the click-catch to turn on the shaft, and by means of the click-spring to make the click-catch engage the teeth of the click-wheel.

But as the carriage moved inwards on some occasions a little further than on others before the click-catch could engage the teeth (owing to the teeth not being always in the same relative position to the click), this caused the winding to commence in some runs later than in others ; and as the winding always finishes at the same time, less yarn was wound upon the spindles in some runs than in others. This was very objectionable, because the yarn was liable to form into snarls when the winding commenced later than it should have done."

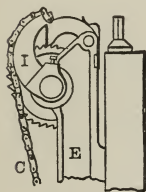


Fig. 77.

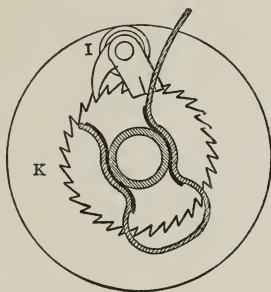
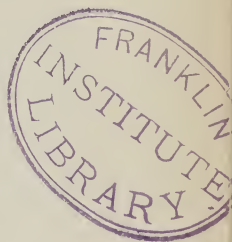


Fig. 78. Enlargement of click and click wheel.

"To remedy this defect, the click, *I* (Figs. 76, 78), can now be engaged before the carriage, *G*, actually begins its inward run, by a very simple contrivance ; consequently the same amount of motion is imparted to the spindles in each inward run after the cop has attained its full thickness, except what is gained by the acceleration due to the nosing motion already explained. In the old arrangement the click was engaged by the click moving round the click-spring, which at the moment was stationary. In the new arrangement the spring is put in motion whilst the click is stationary, one arrangement being thus the converse of the other. For this purpose, the pivot round which the click-spring rotates, instead of being as hitherto a portion of a fixed bracket, is now the centre boss of a lever, *I*, which swings loosely on the shaft of the tin roller, *K*, through a small arc. This lever is actuated at the proper time by a finger, fixed in the connecting rod, *K*, which lifts the "holding-out catch," *C*. This rod receives its motion from the "taking-in lever," as it puts the taking-in friction into gear ; and by means of the lever and



spring puts the click into gear with the click-wheel; this stops the click, and on the carriage moving inwards the winding-on commences. By this means the winding is more uniform in its action, the yarn is subjected to less strain, and it is kept freer from snarls."

Any person who can recall to mind the quality of the yarn produced about twenty or twenty-five years ago, and has the opportunity of comparing it with that of the present day, will be able to estimate the extent of the improvement that has been made. This has all been accomplished by the perfecting of details, which looking insignificant in themselves, in their aggregate have been of the greatest importance.

The mules just described are for spinning medium counts of yarns, say from 24's to 50's. It has been seen that in Hargreaves' jenny one of the leading principles was to deliver a certain quantity of rove from the "clove" or clasp when the carriage was "in," and that this was attenuated by drawing out the carriage, the spindles twisting the threads during its outward run. It has been seen, too, that Arkwright's leading and important feature was to secure this attenuation, or drawing, by means of rollers. The defects of both of these methods, and the great improvement that was effected by Crompton when he combined the two principles in one machine, have been shown. As he constructed his mule, the rollers were made to deliver rove during a large portion of the outward run of the carriage, but before it was completed, say about 3 or 4 inches, these were stopped, and the carriage left to finish the remainder of the run by stretching the threads. By this means all the thick and untwisted parts of the latter were drawn, and rendered approximately even with the remainder of the draw. The advantage of Hargreaves' jenny was thus combined with Arkwright's water frame, and a more perfect thread produced from the mule than could be obtained from either of the preceding machines. At the commencement of the second draw or "stretch,"

—the few inches referred to above—the revolution of the spindles was considerably accelerated, in order to put into the yarn the requisite amount of twist. This, however, could not usually be accomplished by the time the outward run of the carriage was completed, so the spindles were kept revolving for a short time longer. As the processes of preparation were gradually perfected, this “stretch” was diminished, and the speed of the spindles accelerated during the outward run, so as to lessen the final pause of the carriage. Subsequently the desire to increase production led to the invention of means by which this pause was abolished in mules spinning low and medium counts, while to a considerable extent the advantage of the “stretch” was preserved. This was accomplished by further accelerating the revolution of the spindles, and increasing the speed of the outward run of the carriage, as compared with the rate of the revolution of the drawing rollers. Let us suppose the length of a “draw” or distance traversed in the outward run of the carriage to be 63 inches, this length of thread will extend from the tip of the spindles to the front rollers. To spin this length of thread, however, the rollers will only deliver say 60 inches of rove, but instead of the rollers being arrested in the delivery of rove as before, they continue at work until the carriage has completed its outward run of 63 inches, both operations ceasing together, on which the carriage immediately commences its inward run, winding the yarn as it proceeds, thus accomplishing the movement without any loss of time. The accelerated speed of the carriage by which it traverses a distance of 63 inches, whilst the rollers deliver only 60 inches of rove, is termed “the gain” of the carriage; and by the introduction of this change a considerable increase of production was obtained.

In spinning the next higher range of counts, or those known as medium fine numbers ranging from 50's to 90's, the above system has not been found to act satisfactorily. This is probably owing to the yarn being less solidly con-

structed by the new plan as compared with that in which "the second draw" or "stretch," as previously described, is retained. The stretch has the effect of interlocking the fibres more perfectly than can be otherwise accomplished; and as in the finer counts of yarn there are fewer fibres than in the lower numbers it is also the more necessary that this plan should be retained, which it is, in medium fine and fine spinning.

The mule of Messrs. Platt's, above described, which is constructed for medium counts, is also used for spinning medium fine counts. In order to do this it is fitted with a "jacking motion" and a roller delivery motion, by which the rollers are stopped at a certain and regulated stage of the draw, whilst the former continues the action of the spindles, and the outward run of the carriage by which the final twisting and stretching of each draw is accomplished. As previously explained, the primary use of the stretching is to draw down or attenuate those portions of the thread that may be thicker than they ought to be. These are easily attenuated, as they do not take the twist readily until their diameter is reduced to the proper dimensions; the second object of the stretch, as just previously intimated, is to interlock the fibres more perfectly than can be accomplished without this process. The necessity for this will be obvious when the configuration of the fibres is borne in mind. The length of this stretching, or "jacking," as it is technically called, varies according to the kind and quality of the yarn being produced, from nothing up to 4 or 5 inches. It is least in the cases where the cotton is of short staple, and greatest where the fibre is of the longest and most even kind, which is the case where it is intended to be spun into the finest yarns. Practical men prefer an arrangement for accomplishing this purpose known as the sun and planet system, holding it to be the best amongst several competing plans.

Where the system of jacking is adopted, the amount of twist put into the thread during the outward run of the

carriage is reduced to the lowest point, in order to admit of the more perfect performance of the jacking process. When this point is reached the speed of the spindles is greatly accelerated, which has the effect of contracting the thread in the direction of its length, this being a well-known effect of twisting. With the stretch, and the contraction of spinning, there is, therefore, a risk that the yarn may be overdrawn and broken; to provide against this an arrangement has been introduced to set the rollers again in motion and make them deliver very slowly a small portion of roving, by which the danger of breakage and other injury to the yarn, is avoided. This arrangement is known as "the jacking delivery motion of the rollers." There is still another arrangement by which the rollers are started a second time and made to deliver a small amount of roving during the inward movement of the carriage, when the spindles are winding up the spun length of the threads. This is known as "the winding delivery motion of the rollers." The amount of roving delivered can be regulated according to desire; it is usually 3 or 4 inches. Whatever the length may be, it increases the length of the draw by an equivalent amount, and thus adds to the production. This system is found very beneficial in spinning fine yarns, and is in general use.

For spinning the next class of yarns, otherwise the finest numbers, ranging from 80's warp yarn upwards, and 90's weft upwards, the hand mule has been retained to a great extent. Though, however, this is the case, owing to the numerous improvements that have been introduced, the name itself has become almost a misnomer. Great progress has been made in rendering its various movements automatic, or self-acting, to the fullest extent allowable where it was still essential to retain the sensitive touch or control of the hand of the human operative. But this necessity is becoming less and less absolute, as mechanical invention conquers one problem after another, and arrangements are devised that perform with equal skill and greater

reliability the delicate operations that have hitherto needed the keenest observation, and the trained hand of the accomplished spinner. The appliances thus introduced for attaining these ends differ in the machines of various makers, but as all substantially serve the same purpose the description of one will be sufficient. In giving this, several reasons dictate the selection of the one made by Messrs. Platt Bros., described in Mr. Spencer's paper read before the Society of Mechanical Engineers, and previously quoted from. In his description of the mule for spinning fine counts, Mr. Spencer says :—

“The hand-spinner, when backing-off, brings the faller down upon the yarn before he reverses the spindles, so as to uncoil the yarn from them; and the moment the faller touches the yarn both motions act together. To obtain this result with the self-actor, the winding faller, *1*, is depressed by the arm, *н*, and incline, *т* (Fig. 79), just before the carriage, *g*, completes its outward run. At the same time the slack in the backing-off chain, *ж*, caused by this movement is taken up by a modification of the apparatus used for regulating the backing-off chain in the self-acting mule for medium counts previously described. The backing-off snail, *к*, chains *ж* and *л*, and bell crank lever, *м*, remain as shown in Fig. 72. But instead of the tail of the lever, *м*, bearing as before upon the slide of the lever, *н*, it is here made to bear upon an inclined arm, *у*, hinged to a stationary bracket and it is the free extremity of this arm which bears upon the sliding incline, *н*. The elevation of the arm, *у*, is thus gradually increased as the incline, *в*, is traversed inwards by the copping plate connecting rod, *р*, so that it may give the exact amount of tightening motion required for the backing-off chain, *ж*, at each stage of the cop's progress. In order further to modify the backing-off so that it may be suited to the form of the spindles, the eccentric pulley, *в*, is introduced, and the backing-off chain, *ж*, is divided into two half lengths: the upper half coils upon the boss of the pulley, *в*, while the other half, attached to the backing-off snail, *к*, coils upon the eccentric rim. The depression of the winding faller, *1*, is uniform all through the formation of the set of cops; but the position of the locking lever, *к*, and its parts is

constantly varying within small limits, and the compensation required to meet the variations is provided for by this modification of the motion previously described. By these means a very

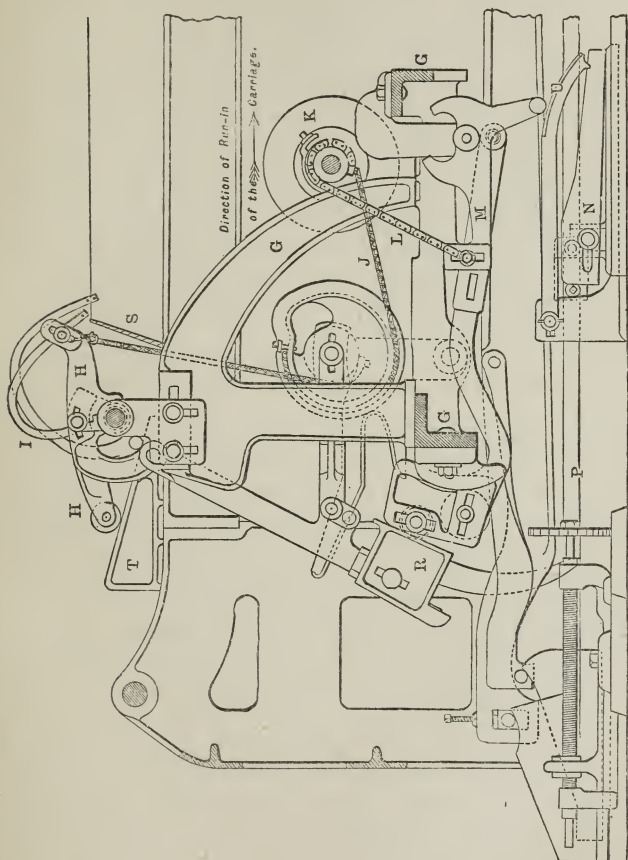


Fig. 79. Self-acting mule for finest counts. Improved faller motion.

delicate action in the backing-off is obtained. The finer the counts of yarn to be spun the slower is the velocity of the spindles when backing-off.

“The yarn having been backed-off from the spindle and the

faller, 1, locked, it is now necessary to wind the yarn on the cop, beginning at the point, or nose, and winding it down to the base of the cone, in preparation for winding upward from the base of the cone to its point. A special apparatus has been introduced into the quadrant motion, to perform this operation in the fine spinning mule. It must be explained that fine yarns are generally doubled after being spun; and for this purpose the cop is mounted on a steel skewer, and placed in the creel of a doubler in a slightly inclined position, free to turn in the creel and allow the yarn to be uncoiled from the skewer. When the yarn is unwinding from the small part of the cop down to its full diameter, the action goes on all right, because there are many turns of yarn to uncoil, and the cop gradually turns on its axis more slowly as the diameter increases. About fifty inches of yarn are uncoiled by the time the full diameter is reached; but in uncoiling the next ten inches of yarn there is a rapid increase in the speed of the cop in consequence of returning so quickly in a few coils from the full diameter to the small diameter at the nose of the cop. This causes the cop to be jerked round too quickly: it then overruns itself and is very liable to break the yarn. The hand-spinner can regulate the number of coils at pleasure, and in practice it is found that about six coils in the height of the cone are sufficient to prevent the cop being jerked round too quickly when afterwards unwinding in the doubler; but to obtain this result by self-acting means is very difficult; and only one solution has been found for it.

“The quadrant motion as originally used is capable of giving an accelerating motion only; but the true requirements of the case demand that it shall be first a diminishing and then an accelerating one, because the winding in each stretch commences on the smallest diameter, then winds down to the largest diameter or base of the cone, and then upwards again with close coils to the smallest diameter, or nose. In practice, however, this has never been fully attained. It is found that by the yielding of the counter faller a compromise is made between the demands of the small and large diameters when winding down to the base of the cone, and as this is only the initial stage of the winding, no harm is done, because there is compensation enough in the rest of the winding, which is regulated to suit the exact requirements of

each stretch. But by the ordinary arrangement of quadrant, after the cop has attained its full diameter, it is impossible to wind more than four and a half coils of yarn upon the spindle, during the time it is winding from the point of the cop down to the base of the cone. The front incline of the copping rail, A, (Fig. 72) has been lengthened to 15 inches, and in some cases to 18 inches (the inclination being diminished, so as to preserve the same absolute rise in the longer incline), under the impression that a greater length of yarn would thereby be wound on the spindles during the putting down of the winding faller. It is not from this, however, that the defect arises; but simply from the want of a sufficient number of turns in the spindles. If a long incline is used the result is simply that the counter faller rises very high and takes up the slack yarn that ought to have been coiled upon the spindles; but when the spindles receive the necessary amount of motion it is found that ten or twelve inches, length of incline is sufficient for enabling six or seven turns of yarn to be coiled on the spindles during the putting down of the faller.

The quadrant is governed by a grooved rope drum, U (Fig. 73), on the quadrant shaft, this drum receiving its motion from the travel of the carriage, G. Ordinarily this drum is a concentric cylinder, so that if the motion of the carriage is uniform, the rotation of the quadrant shaft is uniform, and the angular motion of the quadrant is uniform also. If, at the commencement of the inward run of the carriage, the relative speed of the quadrant in the same direction be reduced, it is evident that more of the chain, R, will be uncoiled from the winding-on drum, H, and more motion will be given to the spindles. This is accomplished by altering each end of the cylindrical drum into a variable scroll of considerably larger radius than the middle portion of the drum which remains cylindrical as before. When the carriage begins to move inwards, it uncoils the rope from the larger radius of the scroll, and consequently imparts a slower motion to the quadrant shaft, and to the quadrant; hence the spindles revolve quicker, and the necessary number of coils of yarn can easily be coiled on them during the putting down of the winding faller. In Fig. 72 the ropes are shown, not upon the scroll part, but upon the cylindrical part, in order to correspond

with the position of the carriage. By the time the large diameter of the cop is reached the rope begins to uncoil from the cylindrical part of the drum, and no further modification of the winding motion takes place until the nosing motion comes into operation. When once adjusted no further attention is required from the spinner. Old spinners long declared it impossible to attain this result by automatic means.

To enable the counter faller to act quickly without straining the yarn, its shaft is now mounted on anti-friction pulleys, and this is found to work advantageously. The hand-spinner could wind the yarn upon the cop without moving the counter faller; but for reasons already explained, this is impossible in the self-actor, the counter faller playing a very important part in the winding, &c. Special arrangements are used in the couplings of the winding faller and counter faller, and in the position of the counter faller relative to the winding faller, but these cannot be dwelt upon here."

In spinning all classes of yarns, the regulation of the two faller wires is of the greatest importance in the production of good work. Should their action not be exactly opportune or harmonious, the yarn is either strained, broken, or left slack, when it runs into snarls, all of which are serious defects, and detract very greatly from the value of the yarn. The automatic regulation of the fallers in all their positions has proved a problem of the greatest difficulty, which it has tasked the ingenuity of inventors to the utmost to solve. The imperfect manner in which it was accomplished rendered it impossible to spin finer yarns than the lower or medium counts upon the self-acting mule for a long time after its invention. Its gradual improvement, however, in this respect has enabled this mule to be successively adapted to higher and higher counts, until it is becoming a formidable rival to the hand-spinner in the higher numbers. The statement of the problem as it affects fine spinning and the means by which it has been solved are given as follow, by Mr. Spencer, in the paper above referred to:—

“*The winding-faller lifting motion.*—The carriage having arrived at the termination of its inward run, it is necessary to lift the winding faller, and then to coil the remainder of the unwound yarn upon the bare spindle, preparatory to commencing the spinning again in the outward run. This is the most important operation performed by the spinner. He allows the carriage to arrive at the end of its inward run before he begins to lift the faller; the spindles are then in their nearest position to the rollers, consequently there is the shortest length of yarn left to be coiled upon the spindles. The relative position of the spindles and rollers, as well as the inclination of the spindles to the rollers, varies with the counts spun, within well-defined limits; the finer the counts the greater the inclination of the spindles to the rollers, and the more obtuse, therefore, the angle made by the spindle and thread just at the commencement of the outward run of the carriage.

“The winding on of the yarn during the run-in of the carriage requires to be regulated so that at the end of the run-in just sufficient yarn is left to coil on the bare tops of the spindles, without either stretching the yarn or leaving it slack to run into snarls. This is the problem to solve. The spinner having regulated the winding during the run-in so that the proper amount of yarn was left to coil upon the bare spindles, brought the carriage to a stand-still, and then slowly lifted the winding faller, while at the same time he regulated the winding so that the yarn was coiled on the taper spindles. As soon as the faller was free from the yarn, he allowed the carriage to start on its outward run for another stretch. He performed these operations with more or less rapidity according to the counts of yarn to be spun. On the medium counts the movements follow each other with almost the same rapidity and regularity as in the ordinary self-acting mule; but as the counts become finer, the division of the operations becomes more marked and deliberate. This is especially so in the ‘Box Organ Hand Mule,’ in which the spinning does not commence until it is set in motion after the completion of the faller lifting. The momentum of the various parts is completely under the control of the spinner, and is practically destroyed.

“In ordinary self-actors the unlocking of the faller takes place

during the run-in of the carriage, but at as late a period as possible. The carriage when near the termination of its inward run, brings the end of the locking lever in contact with the fixed unlocking bracket, and forces the locking lever out of contact with the coping parts of the mule. After the faller is thus unlocked the coping rail has no further control over it. It will be understood from the preceding explanation that the unlocking must be completed before the termination of the inward run of the carriage. In determining how late it is safe to unlock the faller, allowance has to be made for the variations in the speed with which the carriage runs in, owing to the variation in the speeds of the engines and to the condition of the taking-in bands, which affect the momentum of the various parts, causing the carriage sometimes to strike against the backstops very heavily, and at other times to scarcely touch them. This variation affects the unlocking very materially, and causes the faller to be unlocked irregularly. In well constructed mules these variations are reduced to a minimum, but they are never entirely eliminated. The result is, that more slack yarn is left unwound than is required for coiling on the spindles.

“In the apparatus shown in Fig. 80 the operation is effected in the following way. Instead of the unlocking bracket, A, being a fixture, as ordinarily used, it is here mounted on a sliding-bar, which is hinged to the weighted bell-crank lever, B, tending always to throw the stop, A, forwards into the position shown full. Suitable arrangements are made for restoring this apparatus to its normal position, shown dotted, after it has unlocked the faller, I. When in position for unlocking, as shown dotted, it is held back by a catch, C, also of bell-crank shape; this catch is liberated by the carriage, G, striking against its tail at the proper time, but always near the termination of the inward run. The locking lever, R, and its connected parts remain as usual. The unlocking stop, A, is set back, as shown dotted, so that the carriage can go close up to the back stops without unlocking the faller: but the carriage directly forces the unlocking. On the carriage liberating the catch, C, which holds back the unlocking stop, A, the weighted lever, B, falls, and throws the stop forwards against the tail of the locking lever, R, and thus unlocks it just as the carriage completes its inward run. By setting the

catch, c, to be liberated sooner or later by the carriage, the faller can be unlocked at the proper time. In practice it is found that the roller and carriage motions are engaged, ready for another stretch, before the faller, *i*, has lifted clear of the yarn as it is coiling up to the point of the bare spindle. By these means the winding on of the yarn upon the cops is pro-

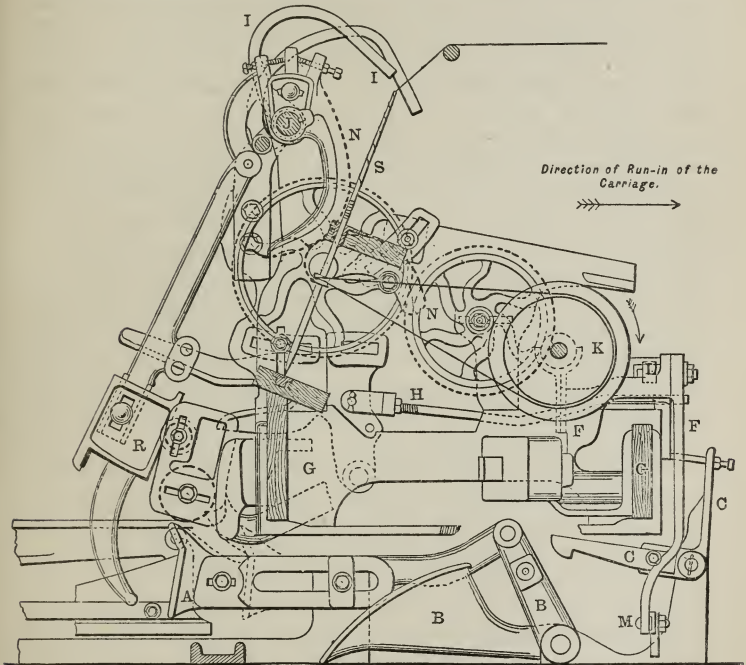


Fig. 80. Faller lifting motion.

longed to the latest period preparatory to coiling the remainder of the yarn on the bare spindle.

"In the ordinary self-actor as soon as the faller is unlocked the yarn is allowed to be coiled on the bare spindle by the momentum acquired by the spindles during the run-in of the carriage, the faller wire being raised quickly out of the way by the lifting springs. The results are very irregular; sometimes

snarls are wound on, and sometimes the yarn is stretched or "cut" as it is called. In the arrangements illustrated in Fig. 80, the tin roller, κ , which drives the spindles, s , is connected with the faller shaft, j , positively, by a train of gearing, so that the tin roller controls the motion of the faller during its rise. The relative motions of the tin roller and faller are not always the same. The motion of the tin roller being assumed as uniform, the motion imparted to the spindles will be uniform also; but in order that the yarn may be guided so as to coil nicely on the bare spindle above the cop, it is obvious that the faller wire must rise most quickly when winding on the largest diameter of the spindle, and the rate of rising must gradually diminish as the spindle decreases in diameter towards the top, thus producing a tapering spiral of yarn on the spindle. To obtain this result a pair of volute wheels are employed, which convert the uniform motion of the tin roller, κ , into a variable motion of the faller shaft, j . This connection of the tin roller and faller shaft must, however, be continued only during the lift of the faller, because the tin roller first set in motion to turn the spindles for lifting the faller, continues in motion during the whole of the outward run, and until the backing-off takes place, whereas the faller must stop rising almost immediately it has coiled the yarn up to the top of the bare spindle.

"The following is accordingly the mode of action. A hollow friction cone, \mathfrak{D} (Fig. 81), is keyed fast on the shaft of the tin roller, κ . Loose on the same shaft is a solid friction cone, covered as usual with leather, and capable of being slid along the shaft into and out of gear with the fast cone. Cast to the loose cone is a pinion, j , gearing into the carrier wheel, \mathfrak{E} , and having a deep flange cast on its outer end; its teeth are also wider than the teeth of the carrier wheel, \mathfrak{E} , to allow of its sliding far enough for disengaging the loose cone from the fast one. On the outer side of the carrier-wheel rim is cast an inclined cheek, \mathfrak{r} , capable of bearing against the inside of the flange on the pinion, j , and so drawing the loose cone out of gear. This pinion has also a groove cut into its boss, into which fits the fork of the engaging lever, \mathfrak{r} , weighted with a counter-weight, which always tends to slide the loose cone into contact with the fast one, and so engage them together. Now

it will be obvious that the lifting motion should be brought into action immediately the faller has been unlocked. If it were put into action too soon, one motion would be acting against the other, and a breakdown would be the result, and if too late it would be useless. To insure both motions working in harmony, the unlocking of the faller is made to liberate the weighted engaging lever, F, and thus allow it to put the friction cones into gear. This is accomplished by means of the connecting rod, H, which forms a lock for the end of the connecting rod, L, the latter being coupled to the weighted engaging lever, F. The

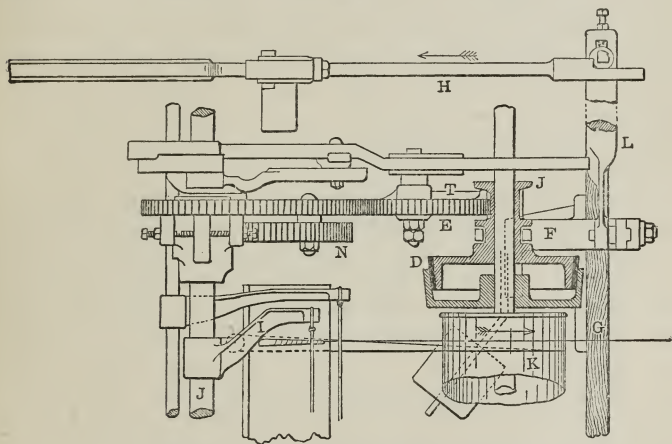


Fig. 81. Faller lifting motion; plan.

two rods work at right angles to each other. On the unlocking of the faller at the end of the inward run, the connecting rod, H, which is worked from the faller lever, R, is pulled forward in the direction of the arrow, until it releases the stud on the other connecting rod, L, and so liberates this rod and the weighted lever, F, which at once throws the friction cones into gear. As soon as the friction cones are in gear, the faller, I, begins to be lifted, motion being communicated to it in the proper ratio from the tin roller shaft, K, by the volute axes, N, N. By the time the faller is lifted clear of the yarn and its work done, the inclined cheek, T, on the side of the carrier wheel, E, has begun to

bear against the flange of the pinion, *j*, and forcing it outwards by its wedge action, draws the friction cones asunder, and thus severs the motion from the tin roller to the faller. This action is a very beautiful one. Self-stopping couplings to the cam shaft are common, but these stop during less than a revolution of the shaft. For the above purpose the stopping must be effected anywhere between a part of a revolution, and three revolutions or more; no two draws are alike, since as the cop is built up, less and less of the spindle is left bare, and therefore the faller has to be lifted less, and the lifting motion must be disengaged earlier. By setting the inclined disengaging check, *t*, of the carrier wheel, *e*, so that the disengagement takes place immediately the faller has risen clear of the yarn, it is always safe. The arc through which the faller has to be lifted is comparatively small, say about 80° , when beginning a set of cops, and becomes gradually less until it is only about 30° on the completion of the cops.

“When the spindles are backing-off, the putting down of the winding faller by the backing-off chain reverses the train of gearing, and removes the inclined disengaging cheek of the carrier wheel, *e*, from contact with the flange of the pinion, *j*. This action would allow the friction cones to be thrown into gear again by the weighted lever, *r*. The carriage, *g*, when near the termination of its outward run, brings a part of the lever, *f*, against the stop, so as to be held by it. The greater the arc of motion of the faller during the backing-off, the greater is the motion of the carrier wheel, *e*, the further is the inclined check, *t*, upon it removed from the flange of pinion, *j*, and the more revolutions are made by the pinion. Whether the faller, *i*, moves through a large or small arc, therefore, it is always liberated from the control of the tin roller at the proper time. The whole operation only occupies about one second. It is the short time allowed which forms one of the difficulties of this difficult problem.

“The stop, *m* (Fig. 80), which keeps the friction cones, *d*, out of gear during the backing-off, keeps them so until the lock, *h*, of the faller, sliding the connecting rod, *h*, inwards, locks the connecting rod, *l*, as explained before, and so holds up the weighted engaging lever, *f*.

“Another important feature of this operation is the speed at which the parts are allowed to work. The speed of the spindles, at the termination of the outward run, is too quick to allow of the use of the positive gearing already described, as it is found impossible to engage the parts sufficiently quickly. This difficulty is further increased by the spindles being quickened to the spinning speed directly the carriage finishes its inward run; for it is impossible to rely upon the momentum of the spindles for continuing their rotation during the lifting of the faller, the results being too variable. To overcome this difficulty, an extra driving belt, called the taking-in belt, is used for driving the self-acting pulley. This belt has generally about half the speed of the main rim-shaft belt, both belts working on pulleys of the

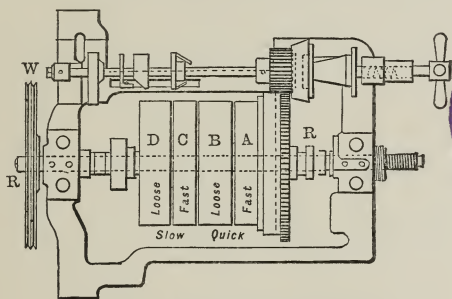


Fig. 82. Plan of driving pulleys.

same diameter on the rim-shaft. Fig. 82 is a plan of the head-stock carrying the main driving or rim-shaft, *R*. The quick driving-belt runs on the fast pulley, *A*, and the loose pulley, *B*, whilst *C* and *D* are the fast and loose pulleys for the slower belt. Both belts receive their motion from the counter shaft, *S* (Fig. 83).

“The cam shaft has three changes in this mule. When the carriage is making its outward run, the quick belt is on its fast pulley, *A*, and the slow belt on its loose pulley, *D*. At the proper time, the cam shaft makes its first change, the rollers are stopped, and, when the proper amount of twist has been put into the yarn, the twist motion disengages the catch, which holds the quick belt on the fast pulley, *A*, and allows a spring to shift it

upon the loose pulley, *B*. This allows the backing-off to take place in the usual way; after which the carriage is caused to make its inward run, and, just before the termination, causes the cam shaft to make a second change, and shift the slow taking-in belt upon its fast pulley, *c*, whereby the rim-wheel, *w*, is then driven at a comparatively slow rate. It is whilst this slower speed has the control of the mule that the lifting apparatus does

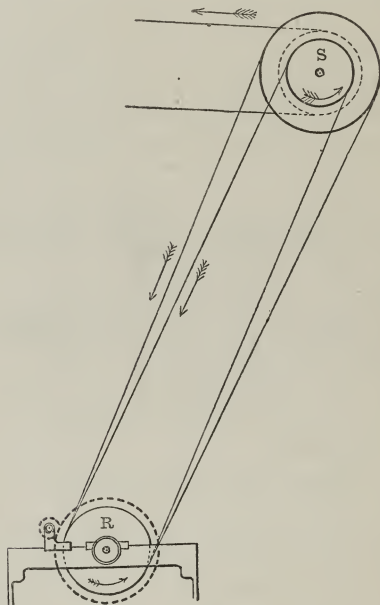


Fig. 83. Driving belts and pulleys.

its work. The slower belt, when first shifted to its fast pulley, acts as a kind of brake on the momentum of the rim-shaft, *R*, and can be relied upon to give the same retardation in every stretch. When the winding faller has lifted nearly clear of the yarn, a finger on it comes into contact with the cam-shaft escapement, and allows the cam shaft to make a third change, which shifts the slow belt back from its fast pulley, *c*, to its loose pulley, *D*, and then shifts the quick belt on to its fast pulley, *A*,

causing the spinning to go on at the proper speed. So rapidly is the whole operation performed that it is impossible to see the change in speed from the slow to the quick belt, though, of course, it is easy to see the movement of the belts from one pulley to the other. The slower the operation, the more perfectly is it done; but it is found to be well done with spindles running at 1,500 revolutions per minute.

“During the outward run of the carriage, the various parts are replaced in their proper positions for repeating these operations. An apparatus is also used by which the winding faller, during the time it is being lifted, is enabled to govern the counter faller in such a manner that the counter faller is free to take up the slack yarn, if any, made during the rise of the winding faller, and is depressed below the yarn as usual, before the spinning commences again. Double speed motions are still used for the finest counts; but as this element would render the previous explanations more complex, it has been purposely omitted.”

The preceding description of the parts of this wonderful machine, and of the function of each part, is so clear and full, that the student carefully reading it cannot fail to easily comprehend it; and the firm from which it emanates stands so high in the trade that it may be accepted as of indisputable authority.

A few remarks on fine spinning on the self-acting mule will appropriately close this chapter. Until within about ten years ago the prevailing opinion appeared to be that, however perfectly the self-acting mule might do its work in low and medium numbers, it could never be adapted to the production of very fine counts. The purely mechanical and inflexible nature of its movements would prevent its yielding in the slightest degree when, as was often the case in fine spinning, conditions required that this should be done. In the self-acting mule experience had shown that the carriage terminated its inward run towards the roller beam at such varying rates of speed that sometimes the back-stops would hardly be touched, whilst at other times they would be struck with such force as to cause great vibra-

tion throughout both carriage and roller beam. This would break down every thread were high numbers being spun. With hand spinning, on the contrary, the spinner could conduct the carriage home so gently as to avoid the final concussion, whilst even if it did occur he could wait until all vibration ceased before re-commencing, by which breakages would be obviated. The self-acting mule, however, being mechanical, could take no cognizance of this varying requirement. Again, the management of the faller wires by a good hand spinner was such as to prevent the breakage of the threads, but against the mechanical action of the faller in the self-actor, the resistance that could be offered by the threads, though sufficient in low and medium counts, would be quite insignificant in the highest counts. Experience for a long time seemed to justify these conclusions. The nice balancing of parts necessary to secure this sensitiveness in the machine, and its accurate performance of the various changes required to be made, were held to be points unattainable in the requisite degree of perfection in the self-actor. In spite, however, of this general opinion, these difficulties have been overcome, and to-day self-acting mules are at work spinning yarns as high in number as 350^s, and which, with the requisite improvement in the preparatory processes, there is no reason to think will not be capable of spinning the highest numbers required. An old-established and eminent firm of machinists in Bolton, Messrs. Threlfall and Co., who have long made a speciality of fine mules, have succeeded in overcoming all the obstacles encountered, and have machinery from their establishment at work both in Lancashire and on the Continent producing as good or better work in the highest numbers than can be obtained from the hand mule. Thus the old organ-mule, which has so long held its ground as the best for this purpose, is being superseded, and will probably soon have disappeared.



CHAPTER X.

THROSTLE AND RING SPINNING. DOUBLING.

The throstle, an improved form of Arkwright's water frame.—Description.—Attempts to improve it.—The Danforth throstle.—The Montgomery throstle.—Shaw and Cottam's improvement.—Doffing, an expensive process; Bernhardt's doffing arrangement; the throstle ceased to be constructed.—THE RING FRAME; its popularity.—Defects of the throstle, the origin of the ring frame.—The throstle in the United States; reasons for its prevalence there.—Invention of the Ring Frame.—Practical defects in it; its rejection in England.—Its improvement, and re-introduction.—Success as a doubling frame.—Slow acceptance as a spinning frame.—The Booth-Sawyer spindle; the Rabbeth spindle.—The ring spinning frame for warp yarn; description; process of spinning; the traveller; the ring; the lifting chain; the lift of the bobbin.—Description of the Rabbeth spindle.—Doffing; the mechanical doffer.—Inclined arrangement of the rollers.—Ballooning.—The anti-balloon ring.—The traveller clearer.—Increasing popularity of the ring frame.—Its use for spinning weft in the United States; the weft frame in England and on the Continent.—Doubling.—Doubled yarns.—The throstle doubling frame; disadvantages.—Improved throstle doubling frame.—Characteristics of throstle-doubled yarns.—The twiner.—Yarns from the twiner.—The ring doubling frame; its popularity.—Description.—The English and Scotch systems.

THE throstle is the second of the mechanical spinning frames calling for notice. As, however, in its principal form it seems likely to be superseded at an early date, a brief description will suffice.

This frame is simply an improved form of the water frame of Arkwright, and a gradual development from it. Compared with the latter, the changes introduced were that all the rollers upon each side were connected and actuated by a train of wheels driven from its first motion shaft. The method of driving the spindles was also improved by the introduction of the horizontal cylinder, which, as already pointed out, was one of the first improvements made in Hargreaves' jenny. The spindles

were furnished with small pulleys or wharves, accordingly as tapes or bands were employed for driving them. The latter in construction were precisely similar to those of the spindle of the single thread spinning wheel, and which Hargreaves had adopted in his machine. Arkwright adopted the wider pulley, in order to obtain more perfect driving. The flyer of the throstle was constructed as in the later form of the water frame, fitted for winding with a traverse arrangement or lifting rail. The legs were solid, with curled or twisted extremities. A piece of wire twisted somewhat like the curl of the leg was mounted on the top, to serve for the eye. From this eye the thread descended, passing around the leg in its course to the curl on its extremity, and thence upon the bobbin. The bobbin was not driven positively, as in the bobbin and fly frames already described, but was fitted loosely upon the spindle, and pulled round by the thread, which, owing to the greater amount of twist put into it, was strong enough for the task. The winding was accomplished by placing the bobbin to rest upon the traverse or lifting rail, and retarding its movement by means of cloth washers. This caused its rate of revolution to fall behind that of the spindle just to the extent that the attenuated rove was supplied by the front or delivery rollers to the spindle. The alternate ascent and descent of the traverse rail filled the bobbin with a succession of even layers. The traverse of this rail was effected by means of a heart-shaped cam, with cranks and levers, an arrangement then and since known as the heart motion. Such was the throstle frame in its earlier form. Subsequently numerous improvements of details took place in its construction, which, as in the case of the mule, brought it to a high degree of perfection some time ago. The old name of water frame, which had been conferred upon Arkwright's machine, was superseded early in the present century by the new one of throstle, at or about the time when the steam engine displaced the water wheel as a motor.

In this state the improved machine was adopted and extensively employed by the trade for the production of special classes of yarns required in both the home trade and for export, and in which solidity and strength were essential qualities. In its best form, as constructed at present, it is very suitable for this purpose. In appearance it differs little from the roving frame, except that its parts are smaller, and its spindles more numerous. The latter have usually had a velocity of 3,000 to 5,000 revolutions per minute; though of late years this has been exceeded, the rate attained having latterly been from 5,000 to 7,000 revolutions. It is, however, questionable whether this higher velocity is not, when considered from an economical point of view, and in relation to its unimproved form, an impracticable rate. In the older form of the frame the spindles were driven from a central shaft placed within, and extending the length of the frame, and which carried a driving pulley at one extremity. This shaft was fitted with a tin cylinder, from which motion was transmitted by means of endless cotton bands to the spindles. Each spindle carries a small wharve, and is supplied with a flannel, leather, or cloth washer, which is put upon it, and passed down to the top of the traverse rail. The flyer is mounted upon the top of the spindle. When ready for work, a bobbin—a small, short tube, flanged at each end—is placed upon each spindle. These flanges are respectively called the head and bottom of the bobbin, and differ in shape, the top one being slightly convex, and the bottom one concave on their outer surfaces. The concave form of the bottom causes the bobbin as it were to stand upon a ring coincident in its dimension with the circumference of the flange. It is constructed thus in order to diminish the friction surface, and so lessen the strain upon the yarn. The bobbin fits loosely upon the spindle, and rests upon the cloth washer. The bolster rail, in many cases, also constitutes the traverse rail; in others, there is an independent traverse rail. The func-

tion of the traverse rail is to carry the bobbin up and down the blade of the spindle, the length of its tube, or rather the space between the top and bottom flanges, in order to wind the yarn in even layers upon the barrel. This is called its "lift," and its dimensions differ according to the nature of the requirement. This method of building up the yarn is known as the cylinder build, as distinguished from the conical build seen in the construction of the cop upon the mule. The traverse is uniform in its length. The twist is put into the attenuated rove, as it leaves the delivery rollers, by the revolution of the spindle and flyer, the thread passing through the top of the latter, and thence around its leg and to the bobbin. The latter being in only slight contact with the spindle has a constant tendency to fall behind it in speed, were it not pulled along by the attached thread. As, however, the latter is being delivered by the rollers, the bobbin drops behind to such a distance as to take up the yarn as spun. When filled, the set is doffed, and the frame again supplied with empty bobbins. In performing this operation the flyers have to be removed from the tops of the spindles, the full bobbins replaced by empty ones, the yarn to be attached to the latter, the flyers replaced, and the frame restarted. In an ordinary size of frame doffing occupies from four to five minutes.

Few of the numerous attempts that have been made to improve the throstle have been successful to any important extent, and its present state of perfection is more the result of improved construction of its parts than of any thorough change of principle. The Danforth throstle, an American invention, in which some radical changes were introduced, was brought before the notice of the trade about the year 1828, but a short experience soon revealed the fact that these were not improvements. Mr. Henry Gore's improvement was the next that demanded public attention, but the advantages claimed from this were soon found to be more apparent than real. Axon's and Brown

and Powell's followed next in attracting notice, but both were soon disregarded as not approaching in practice the claims made on their behalf.

The Glasgow or Montgomery patent throstle was, like the Danforth, of American origin, though considerably improved by Mr. Robert Montgomery, who patented it, and by whose name it was usually known in this country. Great expectations were also entertained of this invention for some time, but they were destined to remain unfulfilled. Its speed was greater, and its production much larger than that of the common throstle. Its chief features were a dead spindle and a rapidly revolving flyer, which had the further peculiarity of being closed. The common throstle bobbin was used in one arrangement, whilst in another, in which the spindle was made to revolve, it wound the yarn upon a tube in the form of a cop.

Many other inventors attempted improvements in this machine, but with small results, until Messrs. Shaw and Cottam of Manchester, in 1848, introduced the plan of driving the spindles by means of two tin rollers in place of one—a plan which prevails to the present day. This was a great improvement, as by its means the bands were enabled to be brought upon the spindle in a horizontal line, instead of at a great angle as before. A further advantage was that the machine, which had hitherto been made of great width, in order to diminish this angle, could be contracted in this respect. This plan has to a great extent superseded “tape” driving.

Doffing, which occupies four or five minutes, and occurring frequently entails a great loss of time, is an expensive process. Efforts, therefore, have often been made to invent a mechanical doffer; but the only one which has been approximately successful is a doffing motion invented by Mr. Bernhardt of Radcliffe, by which the process is accomplished in less than a minute. This plan, however, has not been extensively adapted to the common throstle, perhaps owing to the great importance the system of ring

spinning began to assume soon after the former invention was introduced to public notice. The principle of this doffer has, however, been adapted to the ring frame by Mr. S. Brooks, who has acquired Mr. Bernhardt's interest in the patent. The most recent improvement in the throstle frame is that which is known as the Ashworth long collar, from the name of the inventor. This has been extensively adopted, many frames of the old kind having been altered thereto. During the past four or five years few, if any, of the ordinary throstles have been constructed, the attention of the trade having been concentrated upon the ring frame.


THE RING SPINNING FRAME.—During the past few years this frame has become exceedingly popular, owing to the spread of knowledge concerning its principles and capacity of production, and the great improvements that have been introduced into its details. As it stands now it is probably for the lower ranges of number—say from 10^s to 32^s—the most productive spinning machine in the market. Like the throstle frame, it is a continuous spinner, and is undoubtedly derived from the latter, though it differs from it in important details.

An examination of any one of the series of bobbin and fly frames will render it obvious that, so far as regards the rate of speed, the limit must soon be reached. The centrifugal force developed by the rapid revolution of a spindle carrying a flyer was such as to cause the legs of the latter to fly open, and so to come into contact with one another, to their mutual destruction. To construct them stronger, in order to counteract this tendency, was to load the spindle with a heavier burden, and so to diminish the speed of its revolution, or to expend a greater amount of power in its attainment. In either case, beyond a certain limit, high speed was not an economical success. Hence the production of yarn from a throstle frame, though a continuous spinning machine, did not materially exceed that from the mule, notwithstanding that, spindle for

spindle, the outlay in capital and labour, or the cost of production, was greater for the former. The mule also, for a long time, until the preparation machinery was rendered approximately perfect, had a great advantage in the "stretching" action or "the gain" of the carriage in its outward traverse over the length of rove delivered from the rollers, this enabling it to produce a better quality of yarn than could be obtained from the same material and the same amount of preparation in the throstle. It was owing to these facts that the mule maintained its precedence as a spinning machine over the latter.

The mule, since its growth in magnitude, has required the services of male adults to work it, as it soon passed beyond the capacity of female strength to perform the manual operations required. It may come as information to many persons engaged in cotton mills to-day to hear that women spun upon the mules of about thirty-five or forty years ago, and preceding that time; but the older members of the present generation will be aware of the fact. The difficulties induced by this transition from female to male labour were considerable; but, though the latter was much more costly, it was, on the whole, considerably more economical, when the production from the enlarged machines were considered. In the United States, no such change could be made; masculine labour could not be had, owing to the attractions of the other occupations and pursuits offered by that naturally rich country. It is owing to this fact most probably that the world is indebted for the ring spinning frame. In spite of its disadvantages it was necessary to retain the throstle frame; so the best thing to be done was to improve it, which the mechanics of the United States set about to do.

Accordingly it is from the States we first hear of the ring frame. The Danforth throstle was one of the first outcomes of these efforts, being invented about 1828 by a mechanic, after whom it was named. Great expectations were induced by this invention; but after a short time they

were all disappointed, as it was found impossible to prevent the yarn being snarled every time the frame was stopped to relieve the spindle. The burden of the flyer caused the spindle to vibrate excessively, and soon destroyed it. It was necessary, therefore, to remove it, and it was seen that if a fixed ring could be constructed to take the place of that described by the legs of the flyer, when revolving, the flyer might be dispensed with. The Danforth throstle was an approach to this object, but, springing from an imperfect conception, was a failure. The ring frame appeared immediately afterwards, but its success was prejudiced by the preceding failure of the last-named invention. Its scientific merits, however, prevented it from passing into oblivion, and efforts were steadily made to improve it. It appears to have been invented about 1832 or 1833 by a Mr. Jencks of Pawtucket, Rhode Island, and was introduced into this country within a year or two afterwards. In its first form, as introduced at this time, it consisted of a flat thin ring of the form of a washer, with a hole in it large enough for the bobbin to pass freely through. This was fixed on a rail, so that one ring should be centrically over each spindle; on the inner edge of each ring was a small bead. A small loop made of spring steel, somewhat in this form , was placed on the inner edge of the ring, the loop being opened to pass over it, after which it closed so far as to prevent it from slipping off, but not so closely as to impede its revolution freely around the inner edge. The spindle was short and light, and was operated as in the common throstle. It had a fixed wharve, upon which the bobbin rested, and was secured so as to revolve with it. Such was the ring frame on its first appearance; and the process of spinning being precisely as at present, the revolution of the traveller being opposed by friction and the resistance of the atmosphere to such an extent as to produce the amount of drag necessary for winding purposes. It required little power to drive it at a high speed, and was said to be capable of spinning 80^s yarns of good

quality. The speed recommended by those who tried it was from 110 to 120 revolutions of the front roller of 1 in. diameter for spinning No. 20^s. The yarns produced from this machine were at the time highly spoken of for their excellence of quality in every respect.

It will appear strange at this date to read of the introduction of this machine in such a comparatively perfect state, and yet that almost half a century should elapse before it should win public favour for itself in this country. But the fact was that, though the principle was theoretically sound, there were many practical difficulties encountered which could not be overcome. One of these was the clogging of the traveller with loose fibre, which increased its weight, and finally broke down the threads. Another was the impossibility, with the then mechanical appliances, of so constructing the ring rail that the spindles should be exactly in the centre. Many others were met with which need not be enumerated. The consequence, however, was that its use was abandoned in England, and for many years its existence was almost forgotten.

The means by which it was re-introduced to the notice of the English cotton trade, briefly stated, were as follows:—Mr. Samuel Brooks, machine maker, of West Gorton, Manchester, having sent his representative, Mr. Jas. Blakey, to the United States on a business tour, the latter had his attention attracted to the ring spinning system, and found that it had been so far perfected that it gave promise of soon becoming a formidable rival to the English mule. This led him to inquire exhaustively into the matter, and to examine the merits of the various spindles and machines then competing for the favour of the cotton trade of New England, to which at that time the cotton manufacture was almost confined. Mr. Blakey returned with a report of the thorough success of the system, and brought with him specimens of spindles, rings, cops of yarn, cloth, and everything necessary to illustrate his statements, and to enable him to give full details of the

construction of the frames. This evidence thoroughly convinced Mr. Brooks of the advantages of the system, and of its certainty of superseding the mule for many descriptions of yarn as soon as the prejudices of spinners could be overcome. He, therefore, determined thenceforward to devote his energies to the development of the system and its introduction to the English trade. The doubling frame was the one to which he first gave his attention; and by persistent experiment, and the construction of special tools to ensure accuracy of workmanship, he succeeded in remedying the defects that had been discovered in this frame, and making it highly satisfactory to the trade. The fact that he has since supplied 180,000 spindles to one of the most eminent sewing cotton manufacturing firms in the kingdom, and large numbers to others, is a proof of the success attending his efforts, and of the peculiar value of this system of doubling to the leading sections of that branch of trade, and those making twisted yarns for warps, lace, sewing cottons, crochet, mendings, knittings, and heald yarns. This system has almost superseded the use of the flyer doubling machine, except for very fine or very coarse counts.

Whilst Mr. Brooks was thus perfecting this branch of the ring system, he carried on at the same time a series of costly experiments to perfect the spinning frames, because, though much had been done in the States towards making the ring spinning frame a thoroughly good machine, yet, when it was brought into competition with the highly developed mule of England, it was found that much remained to be done before it could be said to equal, much less to surpass it. For five years not much success attended his efforts in this direction. The difficulties encountered were chiefly in connection with the construction of the spindle.

In the meantime other firms had had their attention attracted to the same field, and ring spinning frames containing the Booth-Sawyer spindle achieved a qualified

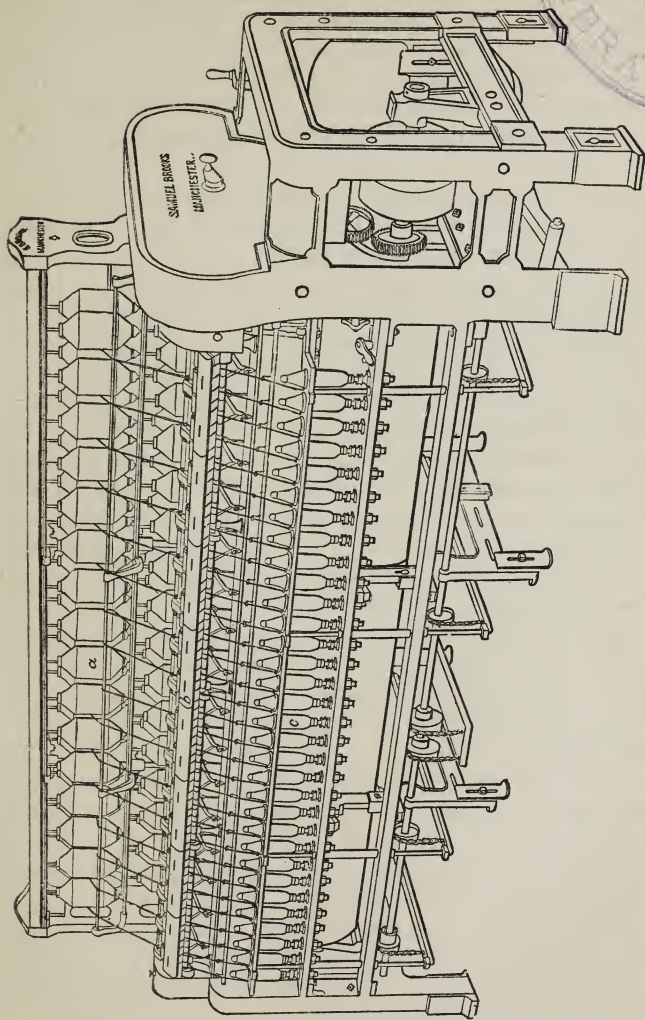


Fig. 84. Ring frame for warp yarns.

success, and succeeded in engaging the attention of the trade. The Rabbeth spindle was soon after introduced by Messrs. Howard and Bullough of Accrington with great success. This invention having become an open one, has since been taken up by most of our machinists, who are now constructing it, with or without specialities of their own.

A view in perspective of the warp ring spinning frame, with a two-height creel, as constructed by Mr. S. Brooks, is afforded by the illustration, Fig. 84. Fig. 85 is a cross section of the same machine, showing a section of the roller stand, mounted on the beam, with rollers and system of weighting; the arrangement of the thread board, and the spindle and bobbin fitted into rail complete; also ring rail, in which is fitted the ring, with travellers complete. A detailed description will be useful to the student. The beam, *a*, carries the roller stands, *b b*, which are so constructed that they give an inclined position to the rollers, *c, d, e*, which are weighted by means of saddles, hangers, levers, wires, and weights, *ff*. The weight upon the rollers can be varied according to requirement. The under-clearers are usually of wood covered with cloth, and keep the front bottom roller clean. The thread rail, *h*, is attached to the shafts, *h¹*, extending the length of the frame on each side, and coupled together by connecting rods and cross shafts, *h², h³*. By means of a small handle placed upon the extremity of the shaft at one end of the frame, all the thread boards with the guide wires are turned up out of the way for doffing purposes. Each thread board, *h*, is also separately hinged to the thread rail, to permit of any one spindle being attended to for piecing the thread when broken. The ring plate, *i*, carries the rings, *j*, which are firmly fixed therein, and on the latter is sprung the traveller, *k*. The bobbin, *l*, is placed upon the spindle, *m*, which is securely fastened in the spindle rail by a nut underneath.

The creel having been supplied with roving bobbins, the

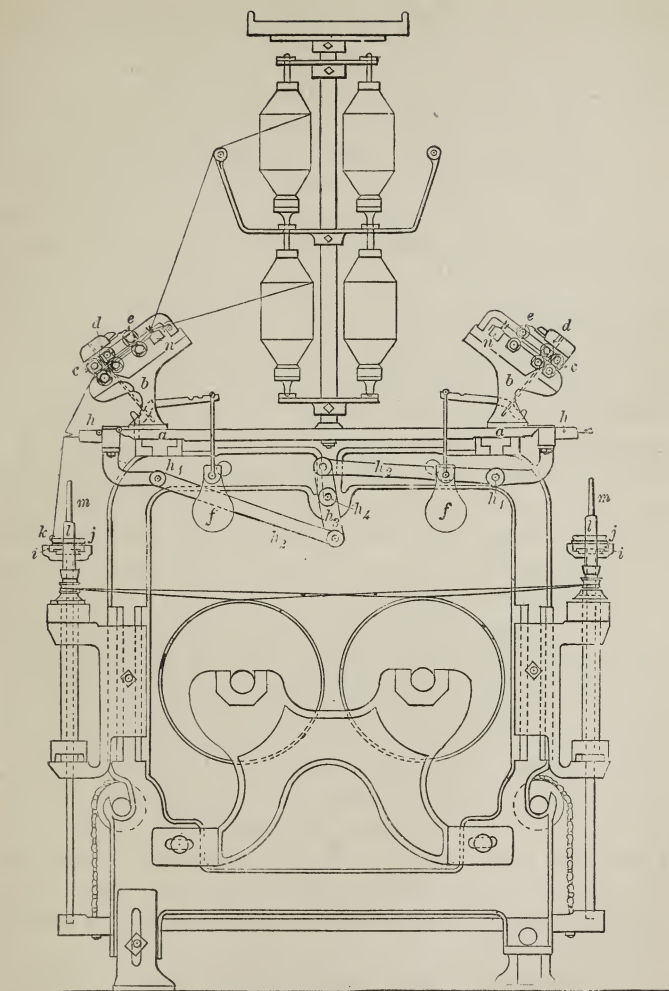


Fig. 85. Ring frame. Section.

ends of the rove are passed through the guide wires on the traverse rod, *n*, and thence between the three pairs of drawing rollers, *c*, *d*, *e*, which act upon it as follows: the first or back pair, *ee*, simply take hold of the roving, draw it from the bobbin, and pass it to the second pair, *dd*. The latter, revolving a little more quickly than the first pair, slightly stretch the roving, conducting it to the third or front pair, *cc*, which, running much more rapidly—say, making five or six revolutions for the second pair one—attenuate the roving to the required thickness for the counts to be spun. The attenuated rove is then passed through the guide wire, which is placed over the centre of the spindle top, thence down to the ring, and through the traveller to the bobbin, *l*, upon the spindle, *m*. The latter, revolving at from 7,000 to 8,000 revolutions per minute, imparts the required twist to the rove, as it is being delivered from the front rollers, *c*, and when thus spun, it is wound upon the bobbins. The top of the ring, *j*, forms a flange, upon which is placed the traveller, *k*, previously described, to form a drag upon the yarn, and thus wind it upon the bobbin.

The size and weight of the traveller requires to be varied according to the counts of the yarn being spun—low numbers requiring the heaviest, and fine ones the lightest. Being made from fine drawn steel wire, the weight of each can be made uniform, and regularity of drag ensured. This is a great advantage over the flyer frame, as in the latter the drag is constantly changing from a minimum weight, when the bobbin is empty, to its maximum, when it is full. The traveller has another function also—that of guiding the thread upon the bobbin, like the curl of the flyer leg in the throstle frame and the faller wire in the mule.

The ring around which the traveller revolves is fixed in the lifting rail, which has a traverse of about $1\frac{3}{4}$ inches, guiding the yarn upon the bobbin in a cop shape, as in the mule, which, it will be remembered, differs from the cylin-

dricul build of the layers of the bobbins in the bobbin and fly frames. At the same time the main chain of the lifting rail is being gradually taken up, thereby giving an additional lift to the rail, by which means, though the copping traverse of the rail remains the same, it passes over a continuously different length of the spindle blade or bobbin upon it, and in this way the copped bobbins of yarn are built up.

The rate at which the lifting chain is taken up is regulated by change wheels, so as to make the bobbin larger or smaller according to the size of ring and counts of yarn being spun. The diameter of ring and length of bobbin varies in each frame according to the range of yarns intended to be spun upon it. The following particulars will illustrate this:—

For 8^s to 12^s, a 2" ring and 6" lift of bobbin should be used.

16	„	20	$1\frac{3}{4}$	„	6	„	„
24	„	28	$1\frac{5}{8}$	„	5	„	„
30	„	36	$1\frac{1}{2}$	„	5	„	„
40	„	50	$1\frac{3}{8}$	„	5	„	„

Owing to the high speed of spindles obtained in the ring frame, it has been found that the design, dimensions, construction, and quality of material are points of vital importance. The spindle most generally in use is the "Rabbeth," of which the following is a description:—Upon the steel spindle, A, Fig. 86, is firmly placed a cast-iron sleeve, B, so as to revolve perfectly true. This sleeve has the lower part turned, to form the wharve, C, for the reception of the band to drive the spindle. The tubular bolster, D, which is a combination of bolster and footstep, is made to receive the spindle; and in the upper part is inserted a tube, E, of metal, which forms the upper bolster bearing of the spindle. This is placed so as to form a reservoir for the oil above it, which it prevents from flowing over the top of the bolster, D, which it would otherwise be liable to do, owing to its being carried upwards by the capillary

action of the spindle when revolving. This tube is made from phosphor bronze, a metal that contains no acid or matter that can chemically affect the oil, or impair its lubricating properties, even after several months working. It will be seen that when the spindle is inserted into its position in the bolster, it revolves in the chamber, H, which

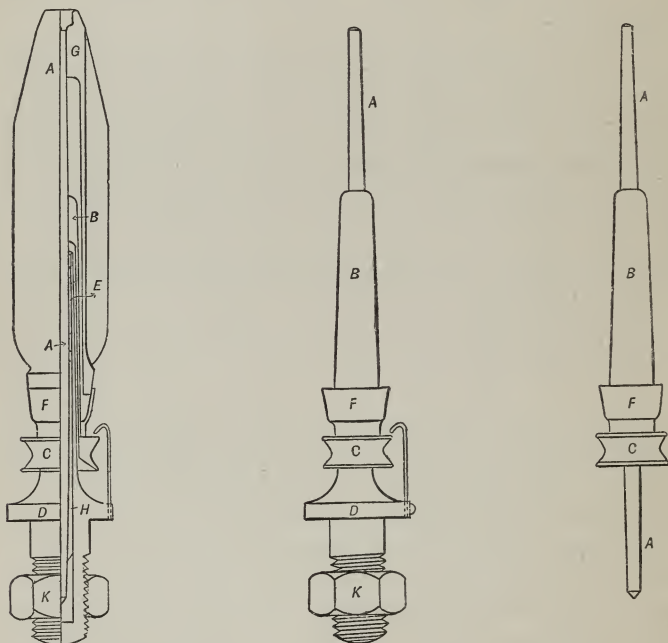


Fig. 86. Rabbeth spindle for ring frame.

is filled with oil, in order to ensure perfect lubrication to its frictional parts. The results of experience show that this method of lubrication is quite effective for a period of about three months. The oil is preserved from all dirt and loose fibre, and is prevented coming into contact with, and staining, the yarn on the bobbin, owing to the mode of

construction of the spindle. The brass cup, F, is securely fastened upon the top of the wharve, C, and receives the bottom of the bobbin, holding it firm and true in its position. It also forms an important feature in the doffing of the bobbin, G.

The doffing or changing of the full bobbin for the empty one is of great importance, as it necessitates upon the common throstle the employment of a special staff of operatives—usually boys, whose sole duties are to perform this operation, the time occupied being a considerable proportion of the whole, and the cost great. The advantages of the ring frame over the flyer frame in this respect is very great, as the doffers are to a great extent dispensed with, and tying by hand of the thread round the empty bobbin is obviated, this being done by means of the brass cup, F. With the mechanical doffer, when the bobbins are full, the attendant, by means of the lifting motion, winds down the ring rails to the bottom of the bobbin, and at the same time stops the frame; then, by means of the shaft to which the thread boards are attached, the latter are turned up at once, leaving all clear for the removal of the bobbins, the doing of which coils the threads around the sleeve. When the empty bobbin is placed upon the spindle, it presses down the thread, wedging it between the bobbin and the brass cup, thus holding it securely, and forming a connection between the rollers and the spindle, so that when the frame is started, the yarn is wound upon the bobbin without any loss of time being incurred in tying up the threads to the bobbins. When the frame has been thus supplied with bobbins, the thread boards are all lowered again into position, and the frame is re-started. The time occupied in doffing a frame of 250 spindles is only about thirty to thirty-five seconds. The bolster is fastened in position by the nut, K; and the vertical wire bent at the top is for the purpose of holding the spindle in position in the bolster when the bobbin is taken off. Improvements in arranging these wires have, however, been patented, by

which all the spindles in a frame can be released at one time for cleaning, oiling, &c.

One great difficulty encountered in the ring system of spinning has been the impossibility of spinning yarn with a "soft" or limited quantity of twist, otherwise very few turns per inch. On the ordinary throstle, the leg of the flyer has intervened to relieve the drag or strain upon the yarn between the roller and the bobbin; and in the mule, the yarn being twisted before the operation of winding on the spindle commences, the difficulty has not existed. On the ring frame, however, the processes of twisting and winding go on simultaneously; and the tender roving, which is delivered from the rollers without twist, is immediately subjected to the full strain of the drag, which frequently causes the yarn to break. The rollers have up to quite recently been mounted horizontally in the stands, and the attenuated rove has remained in contact with the bottom roller nearly three-eighths of an inch below the nip between it and the top roller; thus preventing the twist put into the yarn by the revolving spindle from running directly up to the point of contact between the rollers, which is essential to good spinning. This has led to the adoption of an inclined position for the rollers, as shown in the section, Fig. 85. The new position allows the twine to run directly into the rove immediately it issues from the rollers, thus making a stronger and better twisted yarn, and obviating the difficulty referred to above, in producing a soft twisted yarn, when such is required.

The development of this machine has forced several important problems upon the notice of mechanicians, the correct solution of which have been necessary to make it a success. The increase of speed caused a great amount of vibration of the spindle, and consequently heavy wear and tear. This necessitated a close study of the form and structure of the spindle, the footstep, and the bolster, and their relationship to each other; also, of the best means of lubrication of the friction surfaces. It was a long time before these were

surmounted, but the task was finally accomplished, and the rate of speed greatly accelerated. A second series of difficulties now demanded attention ; these related to the ring and the traveller. It was found that when the speed exceeded a given rate, at a certain portion of the traverse the threads broke down in an excessive proportion, greatly impeding work, and diminishing both quantity and quality of production. The centrifugal force generated by the rapid revolution of the spindle caused the threads to bulge outwards from the vertical position, otherwise to describe the figure of an inverted balloon, from which the name of "ballooning" has been given. When this was at its maximum, the threads came into contact with one another, and were thus broken down. A heavier ring was tried, which had the effect of partially preventing the fault ; but speed was reduced, and the consumption of power was increased. Certain counts, it was also found, would not carry above a given weight of traveller at a specified rate of speed, the drag breaking them down. To avoid lowering the rate of speed, and diminishing the production, thread guards or protectors were devised, which were either plates or rods put into such a position that the threads, in their revolution, should impinge against them, by which the tendency to form the balloon figure above referred to should be held in restraint. These different devices were only partially successful, and the limit of speed, and consequently of production, or of the fineness of the yarn spun, was too soon attained.

Another step forward has, however, been made, and the writer has quite recently had the privilege of inspecting an invention which completely solves these difficulties. This is a little contrivance which he described in "The Textile Manufacturer" of September 15th this year (1883). It is the joint invention of Messrs. Furniss and Young, the manager and spinning-master respectively of Mellor Bottoms Mill, Derbyshire. It is called the anti-balloon ring, and consists of a ring affixed to the traverse, or ring rail,

by vertical brackets, carrying the bar, B, shown in the elevation and plan views, Figs. 87 and 88, to which the ring is affixed by a small set screw. For facility in working, the bars, B, are made of a length sufficient to hold about twelve rings, which are adjusted to the proper spindle gauge, passed upon the spindles, and attached to the rail as indicated. It will be observed that the ring is not a closed one, but that its ends, C, D, are set apart, D being below, and projecting beneath the end of C. This completes the ring-like form, whilst the breach easily admits the thread after being pieced up. It will be obvious that the thread will be controlled at every part of its revolution by means of this ring, and that consequently a lighter traveller can be used, higher speeds can be attained, finer yarns be spun, and a greater production obtained.

The traveller, it was found by experience, gathered around itself a quantity of cotton fibre, most probably from its friction upon the thread passing through it, and a small portion perhaps from that floating in the atmosphere through which it was rapidly passing. As this fibre accumulated, it so much increased the bulk and weight of the traveller as to greatly increase the drag, which broke down the threads. This was an impediment to the success of the ring frame that entailed a good deal of trouble to remove. Again, however, persevering labour was rewarded by success, by the invention of what is denominated a traveller clearer. This is a small piece of metal of appropriate shape for the purpose, which is fixed between two rings, and so near to each that the travellers upon them, in passing, go so near to contact that, whilst not touching, they yet are cleared from loose fibre. Thus was accomplished another improvement in detail essential to success.

The recent rapid increase in the adoption of the ring spinning frame for low and medium counts shows that it is now a practically perfect and commercially successful machine. It is undoubtedly now a formidable rival to the

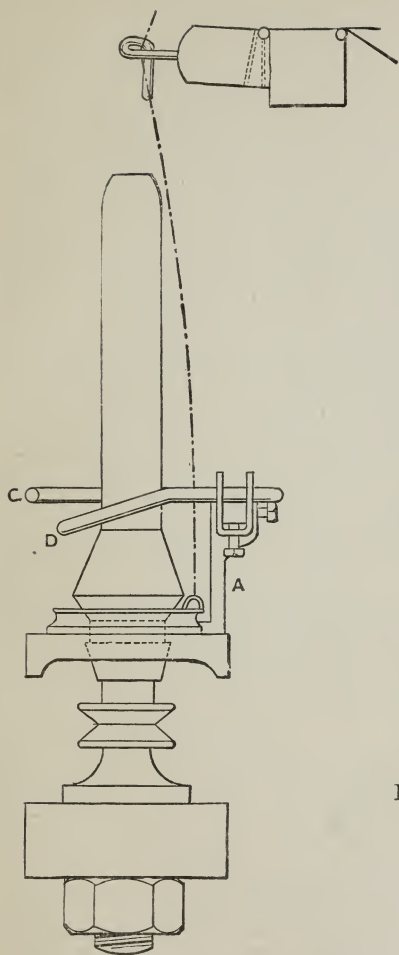


Fig. 87. Anti-balloon ring.

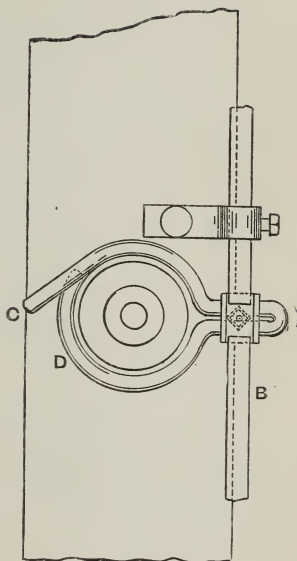


Fig. 88. Anti-balloon. Plan.

mule, and in a very few years the contest for superiority between the two systems will show to which side the victory will finally incline. There is no likelihood, however, that whatever the ring frame may be rendered capable of doing in competition with the mule in low medium and the lower ranges of the fine numbers of yarn, that it will ever displace the mule for fine counts—say, from 80^s and upwards in warp yarns, and 60^s and upwards in weft yarns. The necessarily less twist put into the latter class of yarns will render them unable to carry a ring traveller without such breakages as would greatly interfere with both quality and quantity of production.

In the United States, where, as has been shown, the use of the ring frame is a necessity arising mainly from its social conditions, it is used extensively for the production of weft yarns, but certainly not economically; and were it not for the highly protective tariff in force in that country, it is probable that for this purpose it would have to give way to the European productions of the mule. In this field it holds its own simply by virtue of the protection accorded to it.

Being in existence and use as a weft-producing machine, it necessarily engages attention, and mechanics are labouring continuously to improve it. In the States, the sub-division of the cotton trade into two branches—spinning and manufacturing—as here, has not taken place; yarn is spun and consumed in one establishment, and the difficulties of dealing with the tare and return carriage of empty tubes or bobbins does not arise. Here, with the spinning carried on in one part of the country, and the manufacturing processes in another, distant ten, twenty, thirty, or even more miles away, and by other firms, these are insuperable; and unless the machine can be modified, so as to produce yarns that can be handled and transmitted from place to place with the same facility and cost as mule wefts, its field for spinning this class of yarn in this country will remain a limited one. Mr. Samuel

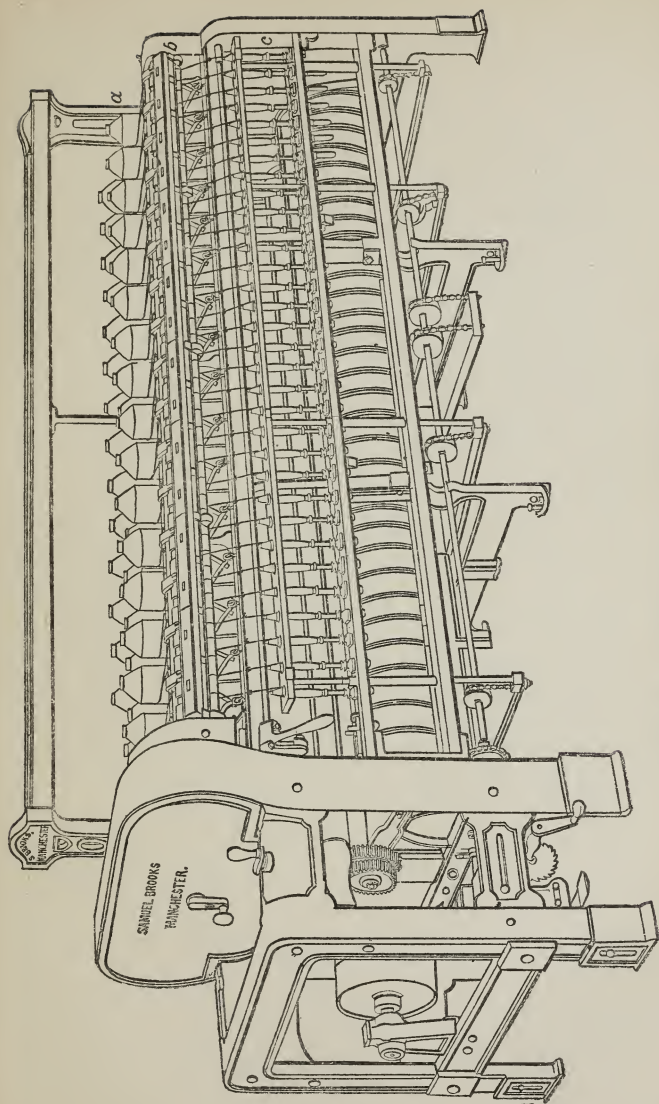


Fig. 89. Ring Frame for spinning weft.

Brooks, so far as we are aware, is the only machinist in this country who has devoted much effort to accomplish this purpose. His labours have met with a fair measure of success. Fig. 89 shows this machine as constructed by him for spinning wefts. It differs little from the warp yarn frame, except in such details as the gauge and size of the spindles and rings, and the substitution of paper tubes for the wooden pirns of the latter. It is meeting with much acceptance on the Continent, where the conditions of the trade are more nearly like those of the States than of this country. Some spinners also in this country, who weave their own productions of yarn, have also adopted it, and its future is regarded as being of a hopeful character. The persistent endeavours made to render it a practicable machine for its designed purpose certainly deserve to be successful.

DOUBLING.—This is a process by which two or more threads are twisted together to form a stronger thread. Such threads are termed 2-fold, 3-fold, 4-fold, 6-fold, 8-fold, or 12-fold yarns, according to the number of single threads each may contain. When described commercially, the count of the single yarn is first expressed thus: 12^s 2-fold, 16^s 4-fold; these are usually written thus: 12^s/2, 16^s/4. Yarns of this kind are much used in manufacturing, and are also extensively applied to many other purposes. They form the warps for numerous descriptions of silk, cotton, worsted, woollen, linen, and other fabrics both light and heavy, including Kidderminster, tapestry, Brussels, and other carpets; they are also employed extensively in the lace and hosiery trade, and for knitting, netting, sewing, crochet, and many fancy purposes. Thus it will be seen that the doubling branch of the cotton trade forms an important portion. It is so extensive, indeed, as to have developed the tendency to become an independent section of the trade, and many establishments exist in which doubling alone is carried on. In others, again, it forms a portion of the spinning division, whether this is on the mule, throstle, or ring principle.

Doubling is chiefly performed on three different machines, all of which are respectively modifications of spinning machines. The first that should be named is the doubling throstle frame, which is the throstle frame modified by the arrangement of the creel for the reception of yarns, and the substitution of the drawing rollers by a single pair of rollers of considerably increased diameter. These rollers in wet doubling are covered with thin sheet brass to prevent corrosion. When delivered from the creel, the yarn passes through water contained in a zinc trough, heated by a steam pipe passing through it, and thence between the pair of rollers which press out the superfluous water it may have taken up. It next passes to the flyer and upon the bobbin. Care is always taken that the twisting it receives shall be in the direction opposite to that of the single thread. The flyers are so constructed that the curls on the legs can be renewed when worn out. In other respects the throstle doubler is simply a counterpart of the spinning frame of that name.

In doubling fine numbers on the throstle several serious disadvantages are encountered. One of these is that after doffing it is necessary to oil the spindles in order to secure that the bobbin shall "slip" and wind properly, so as not to break the threads. The consequence is that many bobbins soon become saturated with oil, the dry porous wood readily absorbing it, whereby the weight of the bobbin is greatly increased, and the drag is rendered unequal as compared with that of bobbins not yet saturated with oil. The result is an irregular yarn. Another evil is that a large number of bobbins are rendered useless. The saturated bobbins also stain the yarn wound upon them, and greatly depreciate its value. Often when a frame has been replenished with bobbins it is found that several will not slip, and the threads after breaking and being pieced several times are rendered unfit for their intended use. These are then stripped with a knife, and the yarn, worth, perhaps, from 1s. to 5s. per lb., is reduced to waste, valued at only a few pence per lb. In numerous

other ways yarn is damaged by saturated bobbins. A great quantity of oil is consumed in the lubrication of the spindles, and a heavy loss is entailed by the necessity of throwing out as unfit for use a great number of the saturated bobbins.

These evils have to a great extent been obviated by an

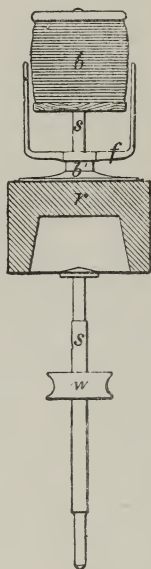


Fig. 90. Improved throstle doubling spindle.

invention perfected and patented by Messrs. Taylor and Ramsden of Bolton, and which is illustrated in Fig. 90. The flyer, *f*, is removed from the summit of the spindle—the position it occupies in the ordinary throstle—inverted, and relegated to the place formerly occupied by the bobbin, *b*. Instead of being made fast as before, it has a boss, *b''*, fixed to it, and is placed loose upon the spindle, resting upon the bolster rail, *r*, with only the ordinary leather washer inter-

vening. The bobbin, *b*, being placed upon the spindle, descends to a position in which it is firmly held. It will thus be seen that with the inversion of their relative positions their functions are also changed,—the drag being obtained from the flyer instead of the bobbin as before. By this change the spindle is reduced one-third in length, and nearly two-thirds in weight, and the flyer one-half. The traverse has been lessened, whilst the diameter of the bobbin has been increased. In this form the spindles can be easily driven at 7,000 revolutions per minute. The advantages are obvious, and will commend themselves to every one practically acquainted with the matter. The bobbin is placed quite away from contact with oil, and revolves with the spindle; consequently, no bobbins are saturated, and no yarn is oil-stained. The flyers not being to take off, doffing can be performed by the minder a spindle at a time, without stopping the frame. This increases production and diminishes expense, dispensing with doffers' wages. The space between the arms of the flyer, which allows the diameter of the bobbin to be increased, rendering it capable of holding more yarn, thus reduces the number of knots made in the winding room, an important advantage in the matter of quality. Bobbins can be used until broken, and a great saving is obtained from this source. There is no waste of yarn from its snarling upon the spindle top as in the ordinary arrangement. A moderate estimate of the gain resulting from this improvement in a mill of say 65,000 to 70,000 spindles will be £1,500 per annum.

Yarn doubled upon this frame, like that of the throstle spinning frame, possesses somewhat similar characteristics. By its passage around the leg of the flyer it becomes more perfectly consolidated, and the loose fibres that centrifugal action would bring to the surface are thoroughly laid by frictional contact, whilst the thread is to a certain extent polished by the same means. Thus it is that a solid, wiry, and glossy thread is obtained which has long been

regarded as the best result of the doubling process, and consequently has stood correspondingly high in the estimation of producers.

The twiner is the next machine that calls for notice. This is a modification of the mule, or more accurately, a return to the principles of Hargreaves' jenny. The twisting spindles are fitted in a bank or fixed carriage, whilst the creel containing the threads to be twisted consists of a traversing carriage which retires from the spindle bank whilst the length of yarn to the extent of its traverse is being twisted. When this is completed, it returns to its first position, the length of yarn being wound upon the spindles in the bank by means of a faller guide wire. There is also another kind of twiner more closely related to the mule, in which the position of the creel and spindles is reversed, the latter being in the traversing carriage. This form is, however, only found when the frame has been transformed from a mule, which is sometimes done when the latter is advanced in wear, but is still too good to break up. Twiners are mostly used for dry doubling.

The yarns produced on both these forms of twiners are not so dense as those from the throstle, not having the advantage of the polishing and consolidating influence of the flyer. Like the single yarn from the mule, its surface is more hairy, the fibre being thrown out by centrifugal action during the twisting process.

The ring doubling frame is the latest competitor for public favour in this section of the trade, and the only remaining one to which attention need be drawn, as the few other machines on which doubling has been, or is yet occasionally performed, are unimportant. Owing to its greater productiveness and other merits, it has sprung to the front of its competitors in public favour, and therefore demands a little more notice. The ring doubling frame, like the others, is simply modified in a similar manner from its parent, the ring spinning frame. Fig. 91 is a perspective view of this important frame as constructed by Mr. Samuel Brooks, and

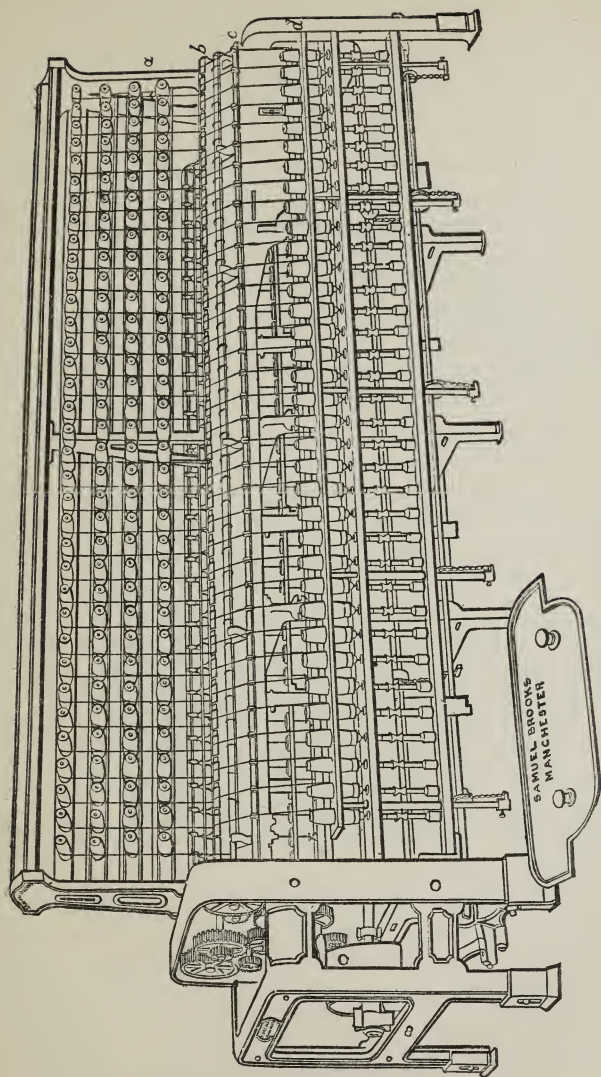


Fig. 91. Ring doubling frame.

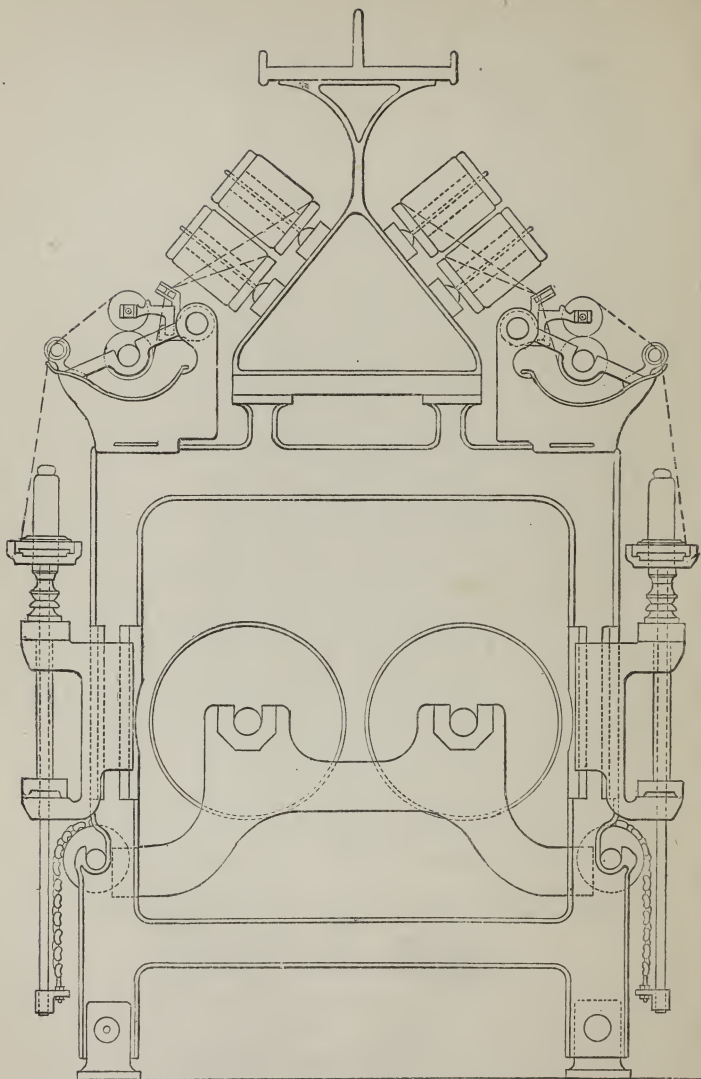


Fig. 92. Ring doubling frame. Scotch system.

of which he has supplied nearly 200,000 spindles to the eminent firm of sewing cotton manufacturers, Messrs. J. P. Coats and Co., Ferguslie, Paisley, and also large quantities to other leading firms engaged in the manufacture of twisted yarns for the same class of trade. In this branch the ring doubling frame has almost superseded the flyer frame, except for the finest or the coarsest counts of yarns. This, Fig. 91, represents the frame as arranged to work on what is known as the English principle, which differs in its details from the Scotch system. Here the yarn-bobbins are arranged horizontally in the creel, *a*, whence the threads descend to the trough, pass through the water, and come over the rollers at *b*, thence through the guide wires on the thread board at *c*, and down to the ring rail at *d*, and, exactly as in spinning, pass through the traveller to the bobbin. The section, Fig. 92, shows the same frame as arranged on the Scotch system. This, it will be observed, differs from the English plan in having the yarn as it comes from the spinning frame first wound upon large bobbins in a winding frame. These large bobbins necessitate a different arrangement of the creel. The threads are conducted down to the trough in which the pair of rollers are arranged, the lower one forming an immersion roller, beneath and around which the threads are conducted, and thence around the upper one to the thread guides and the spindles as before. It will thus be seen that the rollers serve the double purpose of immersing the yarn in the water, and expressing any superfluous quantity of water it may have taken up. As compared with the English plan, where the yarn usually passes under a glass rod in the water, it remains a longer time in the latter, and hence is thought to get more thoroughly saturated. It would be difficult, however, to demonstrate that any particular advantage will be secured by the adoption of one plan as compared with the other; and it may safely be said that the custom of each district is at the foundation of any preference that may be shown.

CHAPTER XI.

MISCELLANEA.

Useful hints.—*To find the area of the safety valve of a boiler.—To find the pressure upon each square inch of a safety valve.—To find the weight on every square inch of a valve where the weight is hung to it.—To find a weight to hang on a valve to resist a given pressure.—Steam engines.—Horse power.—To find the nominal horse power of a condensing engine.—Of a high pressure engine.—To find the indicated horse power.—To find the commercial horse power.—Shafting.—To find speed of second motion shaft.—To find speed of a belt or rope driven power.—Testing cotton.—Card clothing; conditioning.—Oil paint to be avoided.—Covering iron cylinders.—Twist; to find the proper amount.—The twist of slubbings and rovings.—Counts of yarn.—Cotton yarn measure.—Avoirdupois weight used for cotton yarn.—French system of numbering yarns.—To reduce English to French nos.—To reduce French to English nos.—Strength of yarns; table showing; means of ascertaining.—The strength of the cotton fibre utilized in yarns; American cotton yarns; Egyptian.—Filaments in cross section.—Twist for doubling of yarns.*

AS the prescribed limits of this work have already been considerably exceeded, only a few useful hints can be given upon matters that could not easily be incorporated under any particular heading in the previous chapters, or that were overlooked at the time. These consist mainly of practical rules or directions that will be found useful in the various departments of the mill. No pretence whatever is made of covering the whole ground, nor indeed of doing more in this respect than briefly supplementing the deficiencies of professedly practical essays treating of cotton spinning. For calculations and practical rules regarding the various changes in the different departments, the reader is referred to one or other of the numerous treatises already well known.

To find the area of the safety valve of a boiler.—Multiply the square of the diameter of the valve by .7854.

To find the pressure upon each square inch of a safety valve.—Multiply the area of the valve by the length in inches of the short end of the lever for a divisor; the total length in inches of the lever, multiplied by the weight upon it in pounds, will give a number which, divided by the first, will yield a quotient showing the pounds pressure upon each square inch. This rule presumes that the valve and lever are balanced by a counterpoise, and that the only acting weight is that upon the end of the lever. When the valve and lever are not balanced, but contribute their weight to press against the steam, to find if the pressure upon the valve is equal to the pressure of steam against: multiply the area of the valve by the pounds pressure per square inch in the boiler, and the product will be the pressure of steam against the valve; then multiply the pounds weight upon the lever by its length in inches to the fulcrum, and divide the product by the number of inches in the short arm; to the quotient obtained add the weight required to balance the lever, and the sum will show that the pressure upon the valve and the pressure against it are in equilibrium. The weight to balance the lever may be found by applying a spring balance to the lever at the point where it presses on, or is jointed to, the valve. The actual weight of the valve must be added; or if it is attached by a joint to the lever, it will be weighed at the same time as the lever.

To find the weight on every square inch of a valve where the weight is hung to it.—Divide the weight by the area of the valve, and the quotient will be the weight upon every square inch of the valve.

To find a weight to hang on the valve to resist a given pressure.—Multiply the pressure per square inch by the area of the valve, and the product will be the weight required.

Steam engines.—The capabilities of steam engines are measured by a standard, the limit of which is a horse power. This is a force capable of raising 33,000 pounds

one foot high in one minute ; or 1,000 pounds thirty-three feet high in one minute ; or, again, the exertion of a force of 33,000 " foot-pounds " per minute.

Horse power.—There are three forms in which this is expressed : nominal, indicated, and commercial. *Nominal horse power* is the oldest form, and is now rapidly becoming obsolete. It is based upon the area of the cylinder, but takes no cognizance of the steam pressure and speed of piston. It is derived from data met with in the experience of Watt and his immediate successors the early engineers.

To find the nominal horse power of a condensing engine.—Square the diameter of the cylinder in inches, and multiply this by .7854, and the product will be the area. Divide this by 22, the number of inches area for one horse power, and the quotient will be the nominal horse power of the engine.

To find the nominal horse power of a high pressure engine.—Find the area of the cylinder as before, and divide by 11, and the quotient will be the horse power.

To find the indicated horse power.—The area of the cylinder, the number of pounds pressure per square inch on the piston, and the speed of the latter, or the distance it travels per minute, multiplied together for a dividend, and divided by 33,000, will give for quotient the indicated horse power the engine is exerting.

To find the commercial horse power.—Deduct one-third from the indicated horse power for friction of the engine and shafting, and the remainder will be the commercial horse power available.

Shafting. *To find speed of second motion shaft.*—Multiply the number of teeth in the spur wheel of the engine by the number of revolutions it makes per minute for a dividend, and for a divisor take the number of teeth in the driven wheel upon the second motion shaft ; the quotient will be the revolutions per minute of the latter.

To find the speed of a belt or rope driven pulley.—Multiply the number of revolutions of the driver by its diameter,

and divide the product by the diameter of the driven pulley. The quotient is the number of the revolutions of the driven pulley.

Testing cotton.—Of late years cotton has been greatly adulterated, and spinners have suffered correspondingly heavy losses from this cause. Sand and water are the two chief ingredients used for this purpose, either separately or in combination, and it is therefore desirable to ascertain the specific amount of each adulterant. Nearly all the former is left in the opener, intermediate, and finisher lap machine, but the latter evaporates, and hence has received the name of the invisible loss. It is too often, however, confounded with the former. In testing, therefore, let the parcel of cotton, after being carefully weighed, first be exposed for several hours spread open in a room the temperature of which is equal to the maximum temperature of the rooms through which it will have to pass in the working processes. Weigh again, and the loss will be the weight of water that has been evaporated. Next proceed as directed in a previous chapter.

Card clothing.—It has long been a recognized fact that the quality of yarn produced in a cotton mill depends more upon the proper treatment of the material in the carding process than in any other. The most conscientious care is required in this department, and the process of carding should also be guided by an intelligent conception of its requirements. The cotton may be good, and the carding engines the best, yet the product may be quite unsatisfactory. In such cases it will often be found to originate in a defective condition of the card clothing arising from its unintelligent treatment. Cylinders and rollers are often covered with cards that have not been properly conditioned, when, though put on tightly, they soon become flabby and loose. This is owing to the temperature of the room in which they work being so much higher than that from which they were brought. In order to prevent this occurring, all cards should be exposed for several days and

nights in a room the temperature of which is equal to or slightly higher than that of the room in which they will have to work. They should not be taken from here until wanted for use. India-rubber card clothing has to a great extent superseded leather, and this sort requires special treatment. When kept in stock, exposed to a low temperature, it becomes stiff and hard, and if examined would be found to have shrunk considerably. If a cylinder fillet be measured in this condition by stretching it over a long table with a considerable strain to get the fullest possible length out of it, and the same be conditioned and measured again, it will be found to have become practically two or even more feet longer. Were such a fillet put on in its unconditioned state, however tightly it might have been wrapped, the change of temperature would give it the extra length, which would go to slackness, and thus induce endless trouble and bad work. The proper way to deal with cards of this description is to condition them in a room where the temperature is five to ten degrees higher than the room in which they will have to work, by which they will become perfectly flexible and soft. Next, before using, let them be exposed for three or four hours in a temperature the same as that in which they will work. They should then be wound on the cylinders or rollers under a moderate and perfectly uniform strain; and after having been fastened at each end they should be left for an hour or two before the intermediate nailing is proceeded with, in which time the card will have settled or bedded itself into its ultimate position. After this has been done, there will be a slight and uniform contraction, which will bring the card into the best condition for producing high-class work and ensuring durability.

No oil paint of any kind, in any way, or under any circumstances, should be laid on the cylinders before nailing on the clothing. The application of oil paint to cylinders before nailing is a highly dangerous practice, and where india-rubber cards are in question cannot be

too strongly condemned. Oil paints now usually contain petroleum, which is practically non-drying, and when used for this purpose the free portion is absorbed by the india-rubber cloth forming the card's foundation, which is thus quickly decomposed or rendered rotten. Should the foundation be dry, but not perfectly hard, the crowns of the teeth sink into the yielding substance, become rigidly fettered, and consequently broken.

In covering iron cylinders, the best and safest covering will be found to be stout calico, laid on with freshly made flour paste. This, before being covered, should be thoroughly dry. Calico thus applied constitutes a non-conductor between the cold iron and the india-rubber, and thus tends greatly to the preservation of the latter. Considerable alternations of temperature are highly injurious to india-rubber, destroying it in a short time; whilst where it is strictly preserved from paint, grease, and these changes in a reasonable manner, the cards will last almost as long as the machine itself. It has not unfrequently occurred in the experience of the best card-makers that their cards have worked for twenty years when properly cared for in these several respects, whilst, when neglected, they have been destroyed in four or five years.

When cards are mounted on the bare iron, the surface of the latter should be made thoroughly clean. Care should be taken where the traversing grinder is used, that oil does not drop from it upon the cards. Much mischief often arises from the use of unsuitable hand-strippers, which, if too strong and unyielding, are the cause of rapid and irreparable damage to the cards. "A little extra labour bestowed upon the mounting of the cards," say Messrs. James Walton and Sons, the eminent card-makers of Denton near Manchester, in a circular of instructions upon the treatment of cards, and from which we have condensed most of the above remarks, "will save endless trouble and disappointment afterwards."

Twist.—In order to find the proper amount of twist per

inch to put into any counts of yarn spun on mules, the rule is to multiply the square root of the counts by $3\frac{3}{4}$, when the yarn is intended for warps; when for weft, the square root is multiplied by $3\frac{1}{4}$. These numbers are what are called standard numbers, and the twist thus obtained is found to be such that the yarn will set without running into kinks. More twist might make a stronger yarn, but other inconveniences are introduced when that obtained by the above means is exceeded. Warp yarns require spinning comparatively hard and firm, in order the better to bear the strain and friction of subsequent operations. Weft yarns, on the contrary, need to be spun with less twine, as it is desirable, for several reasons, that the latter should break at a less strain than the warp yarn into which they have to be inserted. Also being less consolidated, they give greater fulness in appearance, and a better feeling to the cloths. For yarns in the lower ranges of numbers spun from American cotton, and higher counts from Egyptian or Sea Island, the above rule will apply very well, but for counts higher than 32s. in American some spinners prefer for warp yarn to multiply the square root of the count by 4, and for wefts by $3\frac{1}{2}$. In Surat yarns, even this is slightly exceeded. The twine thus obtained is of course what is called an average or medium amount; there are special classes of yarn called "soft spun," in which the twine is less; and, again, other descriptions called hard spun, in which the average is exceeded more or less according to requirement. Yarns spun on the throstle or ring frame have usually from $\frac{1}{2}$ -turn per inch in the lower numbers to $1\frac{1}{2}$ in medium counts more than mule spun yarns.

The twist of slubbings and rovings.—The late Mr. Evan Leigh, in his work on cotton spinning, gives the following as "a secret worth knowing." "It is," says he, "a common thing to turn the spindles of slubbing, intermediate, and roving frames all to the *right* or *twist* way. The effect of this may be best illustrated by endeavouring to make a

rope of many strands twisted all one way. The tendency of such a rope would be to curl up and untwist itself; but if the strands are twisted one way when single, and the contrary way when doubled together, the rope will lie straight with the twist in it. Suppose, then, it is required to spin twist (warp yarns) from double rovings, and there are slubbing, intermediate, and roving frames, with the ends or bobbins doubled behind the intermediate and roving frames as well as in the mules, the proper thing to do is to twist the slubbing to the *left*, the intermediate to the *right*, the roving to the *left*, and the mule to the *right*. The effect of this is to a certain extent to make the yarn like a cable, the fibres of the cotton being interwoven together. Both the intermediate and the roving frames would work better, and the mules spin better, and the yarn would be sounder and freer from crackers or weak places. More twist may also be got into it, and there will be less disposition to curl." When it is required to spin weftwise, or to the left, with double roving in the mule, this proceeding must be reversed. "It must be distinctly understood that it is of no use to reverse the spindles, *except where a doubling takes place at the back*; otherwise it is twofold loss of the twist in the roving." "Attention to the above cannot be too strongly impressed upon spinners, as the advantage to be derived from it is very great."

Counts of yarn.—The denomination of yarns in this and other countries where the English system prevails is obtained from the number of hanks of 840 yards each in the 1 lb. Troy. Thus, of 20s. there are twenty hanks, of 30s. thirty hanks in 1 lb., and similarly with other counts.

Cotton Yarn Measure.

54 inches =	1 thread (or circumference of wrap reel)
4,320 ,, =	80 threads = 1 lea.
30,240 ,, =	560 ,, = 7 leas = 1 hank, or 840 yds.

Avoirdupois Weight used for Cotton Yarns.

24	grains	=	1	dwt.					
109 $\frac{3}{8}$	"	=	4 $\frac{1}{9}$ $\frac{7}{2}$	dwts.	=	$\frac{1}{4}$	oz.		
218 $\frac{3}{4}$	"	=	9 $\frac{1}{9}$ $\frac{1}{6}$	"	=	$\frac{1}{2}$	"		
437 $\frac{1}{2}$	"	=	18 $\frac{1}{4}$ $\frac{1}{8}$	"	=	1	"		
7,000	"	=	291 $\frac{1}{3}$	"	=	16	"	=	1 lb.

French System of Numbering Yarn.

1,000	metres	weighing	500	grammes	. . .	is	No. 1.
1,000	"	"	250	"	. . .	is	No. 2.
1,000	"	"	50	"	. . .	is	No. 10.
1,000	"	"	25	"	. . .	is	No. 20.

Rule : Divide the number of metres reeled by twice the weight in grammes.

French No. 1 = English No. 1·18.

TO REDUCE ENGLISH TO FRENCH NUMBERS, divide by 1·18.
TO REDUCE FRENCH TO ENGLISH, multiply by 1·18.

Strength of yarns.—The following figures showing the strength of different counts and qualities of yarns are abstracted from the tables recording the results of a series of valuable experiments made by Dr. Bowman, of Halifax, and given in his recent excellent work, the "Structure of the Cotton Fibre," a perusal of which is strongly recommended to the reader :—

Samples.	Description and quality of yarn.	Breaking weight per lea in lbs.	Average weight per lea in grains.	Actual counts.
A	20 ^s single, mule spun. All American cotton	78.8	49.514	20.19
B	20 ^s single, mule spun. American and Egyptian cotton	102.2	50.531	19.795
C	20 ^s single, water twist. All American cotton	79.5	48.904	20.445
D	32 ^s single, mule spun. All American cotton	54.7	31.629	31.63
E	40 ^s single, super Bolton mule yarn. All Egyptian cotton	54.4	25.259	39.585
F	50 ^s single, super Bolton mule yarn. All Egyptian cotton	35.2	19.974	50.06
G	60 ^s single, super Bolton mule yarn. All Egyptian cotton	32.3	16.934	59.06
H	60 ^s single, super combed mule yarn. All Egyptian cotton	33.4	17.036	58.70
I	40 ^s 2-fold full twist Twiner yarn. All American cotton	101.8	52.077	19.19
J	40 ^s 2-fold full twist Twiner yarn. All Egyptian cotton	107.4	52.230	19.14
K	40 ^s 2-fold super frame yarn. All Egyptian cotton	108.9	49.891	20.04
L	38 ^s 2-fold super frame yarn. All Egyptian cotton	131.	52.581	19.01
M	60 ^s 2-fold super frame yarn. All Egyptian cotton	73.8	33.177	30.14
N	60 ^s 2-fold Twiner yarn. All Egyptian cotton	85.5	33.090	30.22
O	80 ^s 2-fold Twiner yarn. All Egyptian cotton	61.	25.878	38.64
P	120 ^s 2-fold frame yarn. All Egyptian	51.4	16.750	59.70
Q	120 ^s 2-fold super combed frame. All Sea-Island.	63.6	16.715	59.82

In each case the above particulars represent the average of twenty tests made with four separate samples of each yarn, five tests from each thread. They may thus be regarded as fairly exhaustive.

The samples represented various spinnings, and were not picked ones, but all were from good makers. The

room in which the tests were made was kept at a uniform temperature by a steam stove, and all the samples of yarn were exposed for twenty-four hours before testing in order to secure the same conditions of temperature and moisture, which it is well known affect the strength of yarns. The tests were made by the most perfect appliances in use for the purpose, consisting of a reel fitted with a traversing motion, and an arrangement to secure a uniform tension on the threads during the reeling operation. The scales used for weighing the leas were a chemical balance which turned readily with the $\frac{1}{1000}$ th part of a grain when the scale ends were loaded with 500 grains each. The strength-testing machine was of the ordinary form in use, but instead of being operated by hand power, which varies and appreciably affects the result, it was worked by a band, transmitting power from a shaft driven by the engines of Union Mills, Halifax, belonging to Messrs. Bowman Brothers, and which, for all practical purposes, were perfectly uniform and steady. In the samples A, the greatest variation in strength was from 73 to 86 lbs. = 16·5 per cent.; in weight it was from 47·83 grains to 52·31 or 4·48 grains, about 9 per cent. This was regarded as a good commercial yarn. Sample B was more uniform, extreme variation in both strength and weight being only 8 per cent. A first-class yarn. The next, C, a good using yarn, varied about 11 per cent. in strength and 6·4 per cent. in weight. The next specimen, D, was of a favourite Lancashire yarn which in its extreme varied 18·2 per cent. in breaking strain, and rather less than 10 per cent. in weight. Sample E, a first-class 40^s spun down from 60^s rovings, shows no more than 7·3 per cent. variation in strength, and less than 2 per cent. in weight. Sample F, from the same roving, does not give as good a result, strength varying 22 per cent., and weight 6·5 per cent. G was a first-class carded yarn, which varied at its highest 15 per cent. in its strength, and 6 in its weight. The next, H, was a super combed yarn, one of the best in the

market, and its greatest variation in strength was 12 per cent., and in weight 6 per cent. The remainder are "two-folds," and exhibit, generally speaking, similar results, though the variations are not quite so extreme in either strength or weight.

The strength of the cotton fibre utilized in yarns.—Another most interesting inquiry undertaken by Dr. Bowman, and the details of which are given in his work, was as to how far in the manufacture of yarns the natural strength of the cotton fibre is utilized. The first step in this search was to ascertain the weight the individual fibre will carry without breaking; next to count the number of fibres in the cross section of a yarn; multiply the former by the latter, and the theoretical weight that the yarn should lift is obtained. A comparison of the latter with the actual strength, as tested by experiment, gives the percentage of the natural strength utilized. The following tables, which we extract from Dr. Bowman's work, are very instructive and interesting regarding this point. Of course an approximately correct result is only possible, as in the first place the assumption, as observed by Dr. Bowman, that the separate fibres are of uniform strength, is not well founded. Several other circumstances also militate against a correct result being easily obtained.

AMERICAN COTTON.

Counts and description.	Average number of fibres in cross section of thread.	Calculated strength per lea in lbs.	Observed strength per lea in lbs.	Percentage of total strength utilized.	Percentage of total strength lost.
20 ^s water twist . .	230	388	80	20.6	79.4
32 ^s mule twist . .	144	240	50	20.8	79.2
40 ^s " " . .	120	194	40	20.6	79.4
50 ^s " " . .	92	155	30	19.3	80.7
30 ^s two-fold . . .	300	500	130	26.0	74.0
40 ^s " . . .	225	380	100	26.3	73.7
50 ^s " . . .	180	300	75	25.0	75.0

EGYPTIAN COTTON.

Counts and description.	Average number of fibres in cross section of thread.	Calculated strength per lea in lbs.	Observed strength per lea in lbs.	Percentage of total strength utilized.	Percentage of total strength lost.
40 ^s single mule . .	161	234	50	21.3	78.7
50 ^s " " . .	129	188	38	20.2	79.8
60 ^s " " . .	107	156	30	19.2	80.8
40 ^s two-fold . . .	320	450	120	26.6	73.4
50 ^s " . . .	240	360	96	26.6	73.4
60 ^s " . . .	200	300	83	27.6	72.4
70 ^s " . . .	180	255	70	27.4	72.6
80 ^s " . . .	160	220	60	27.2	72.8
90 " . . .	140	200	50	25.0	75.0

The number of filaments in the cross section of threads of the same counts is not always alike, this depending upon the nature of the cotton used. In the above calculations Dr. Bowman took the average when Middling Memphis cotton with staple and fully good fair Egyptian was used. The calculation assumes that all the fibres are sufficiently twisted into the thread to prevent slipping or drawing out without breaking when strain is applied, but as this is never perfectly accomplished in practice, a considerable allowance must be made on this account, especially in slack-twisted yarns. Indeed, it will probably be found that it is here where the great loss which appears between the theoretical and the actual strength of yarns arises. In the tables, however, no such allowance has been made, as it was found practically impossible to fix any satisfactory data on which to make it. Much also depends on the amount of twist put into the yarn for preventing the slipping of the fibres. The investigation, however, was made with yarns containing the standard twist per inch obtained by multiplying the square root of the counts by 3.75, as has been stated previously. It is curious to see that whether the yarns are made from American or Egyptian

cotton, very little more than 20 per cent. in single yarns of the theoretical strength of the fibres is utilized. In two-fold yarns a better result by about 6 per cent. is obtained. The percentage of loss increases in both cases as the yarns become finer. In making these tests yarns were in all cases used, spun down from the highest counts in order to obtain them from the same cotton: that is to say, the American single yarns were spun down from 50^s rovings, and the Egyptian singles from 60^s rovings; and similarly in the two-folds, all the Egyptians being from the same rovings and cotton as the 90^s/2. The result shows that there is room for further improvement.

Twist for doubling of yarns.—Yarns after their first spinning are often twisted together again in two, three, four and many other folds for various requirements. This process is technically called “doubling,” a name which it is obvious only very imperfectly describes it. Several strands thus produced from two or more threads are frequently again put together, making a cord of any number of threads according to requirement. The amount of twist or twine to put into the article at the respective doublings is often a difficulty to those having charge of the operations, especially as practical men differ about the matter. The consequence is, that yarn is sometimes spoiled in the endeavour to feel the way to a proper result. The best practice is to follow the principle laid down for obtaining the twist in spinning single yarns. Yarns doubled on that principle will lie straight as in the single state. Suppose 100^s has to be doubled into two-fold; two threads of 100^s put together, the joint thread would be 50^s, the square root of this number is 7.05, which multiplied by $3\frac{3}{4}$, or thus, 3.75 gives 26.43 for twist. If the doubled yarn be wanted of a soft texture, then the square root as obtained above should be multiplied by $3\frac{1}{4}$, when the twist will be such as will set without curl. When curl is required, an additional percentage to the above twist must be put in. In all cases the twist should be put in in the direction

opposite to that of the last preceding process. Suppose now three strands of this $100/2$ fold be laid together, and it is wanted to know the proper twist to put into the six cord which it has thus become. Let it be assumed that the operation was commenced with yarn of true counts ; that is 100^s , the doubling makes this into 100^s two-fold, or counted singly 50^s . But if measured and weighed out this yarn would not contain more than 48 hanks to the pound, and the reason of this is that the twining of the threads together reduces the length by about two hanks. Hence it is necessary, when a true length is required, to start with yarns higher in the actual than the nominal count. The three strands of the twofold 100^s having, as we have seen, become, not 50^s but 48^s , three of these laid together now reduce the counts to 16^s ; the square root of this number is 4, which multiplied by 3.75 gives 15, the number of turns per inch required at this stage. This process followed throughout will give satisfactory results. When the yarn is wanted to curl, it is usual to add about 20 per cent. to the twine obtained by this principle. For knitting yarns three folds, which are required to be soft, a rule in extensive use is to multiply the square roots of the yarns (single) by $2\frac{1}{4}$, and the result is the turns required. Crochet yarns follow the same rule, but require 2 for a multiplier. Embroidery cottons (four-folds) use the same standard number, 2, as the last-named.

APPENDIX
ON STEAM BOILERS AND ENGINES.

APPENDIX.

ON STEAM BOILERS AND ENGINES.

Cotton mill boilers.—Dimensions.—Furnaces.—Flanging; boiler power; evaporative power.—To estimate the number of boilers required.—Inspection; cleaning; safety valves; low water alarms; pipes, feed, and steam connections.—Boiler setting, with illustrations.—Engines.—Economizers.—Feed water temperature.—Position of economizer.—Chimney draught.—Oil consumption.—Driving.—Mechanical stokers.

THE author is indebted to Mr. W. H. Booth, of the "Mechanical World," and formerly of the Manchester Steam Users' Association, for the following remarks upon steam boilers, engines, &c., in connection with which he has had an extensive experience. Acknowledgment is also made to the proprietors of the above journal for the accompanying illustrations.

The boilers used to raise steam for either motive power or other purposes in the cotton trade are so universally of the Lancashire or internally-fired two-flued type, that we shall confine our remarks wholly to that type of boiler.

The making of boilers now ranks equal with, if not superior to the manufacture of steam-engines, and great care and skill are brought to bear upon their construction. The chief centres of the boiler-making trade in the cotton districts are Manchester, Hyde, Dukinfield, Blackburn, Bolton, and Preston. For some years past the standard size of Lancashire boiler has been 27 or 28 feet in length, with a diameter of 7 feet; and such a boiler, if double riveted, would be made from $\frac{7}{16}$ ths iron to stand 75 lbs. pressure, but during the three years ending December, 1883, the use of steam of 100 lbs. has become more common, and steel

has become the material of construction, while at the same time the diameter has been made 7 feet 6 inches, and the thickness of steel plates for 100 lbs. will be half an inch, and the boiler may be worked to 105 lbs. safely.

Furnaces, also, are made of steel, and should not exceed $\frac{3}{8}$ ths in thickness of plate, indeed $\frac{5}{16}$ ths is not an uncommon dimension.

Resistance to collapse is best obtained by means of the flanged seam, and in the writer's opinion it is desirable that the flanges should be turned upon a properly-shaped block by means of wooden mallets, as the flanging-machine is very severe upon plates, though, perhaps, cheaper than hand flanging. Hydraulic pressure is also suitable as a flanging agency, and preferable to a roller flanging machine. Boilers are now almost invariably made with flat ends, which require to be about $\frac{1}{16}$ th inch thicker than the plates of the shell. These flat ends are attached to the shell by a circumferential flange or angle iron, as shown in Fig. 95, and they are stayed by means of five gusset plates at each end above the furnace tubes, and by two at the front and one at the back end below the tubes. There should be at least a distance of 10 inches between the circle of rivets attaching the tubes to the end plates and the lowest of the rivets attaching the gusset stay angle irons. If longitudinal stay rods *are* inserted, they should not be drawn tight, but should be slack enough to easily vibrate sideways 4 inches, and should be attached to the end plates by an inside and outside nut and washer. The distance apart of the stay bolts, which are two in number, should not exceed about 14 inches. In fact they should be placed as near together as the centre gusset will allow.

All manhole and mudhole mouthpieces, and the blocks for the attachment of the steam, safety valves, and other branches, should be of wrought iron or steel; cast iron is quite inadmissible above 75 lbs. pressure.

The strengths given as safe to adopt are, of course, on

the assumption that materials and workmanship are of the best.

With a standard 7 feet diameter boiler, there would be two furnaces 2 feet 9 inches diameter. The fire-grates would be 6 feet long, thus giving 33 square feet of grate surface. Such a boiler would be easily worked at fifteen tons per week of coal. It would burn eighteen tons comfortably, and twenty-one tons is a frequent rate of consumption, but it is not advisable to exceed twenty-five tons per week; though at times of cleaning one of a pair of boilers, the writer has known thirty tons to be the rate of consumption in the boiler at work, but it is not economical to burn at such a rate. Two ordinary standard 7 feet 6 in. Lancashire boilers may be considered fully equal to supplying steam for 500 indicated horse-power in engines burning $2\frac{1}{2}$ lbs. of coal per indicated horse-power per hour, the coal consumed per week being under sixteen tons per boiler. With modern engines of good design the consumption of coal per indicated horse-power may be taken at about $2\frac{1}{2}$ lbs. per hour. If the boilers evaporate an average of 8 lbs. of water per pound of coal, this is equal to 20 lbs. of water per indicated horse-power per hour, and on this basis may be calculated the boiler power required. Thus, if we know that our mill of 70,000 spindles will require 900 horse-power to drive it, we may say that it will require $900 \times 20 = 18,000$ lbs. of water per hour. Dividing this by 8 gives 2,250 lbs. of coal, which in a week of fifty-six hours will amount to fully fifty-six tons. Reckoning to work our boilers at fifteen tons each, gives four boilers, to which it is good economy to add a spare boiler, making five in all.

In estimating the number of boilers required, the following formula may be used:—Where I. H. P. equals number of indicated horse-power required, and N equals number of boilers, $N = 1 + \frac{\text{I. H. P.}}{240}$. This allows for a spare boiler, and easy working.

It is advisable to have boilers periodically inspected. To secure satisfactory inspection, which should be thoroughly effected every year, the boiler should be emptied and cleaned out, and all scale removed.

The flues should be thoroughly swept, and the fire-bars and bridges wholly removed. Care should be exercised in using disincrustant compositions, and, on the whole, there is nothing better than common soda or soda ash, and the blow-out tap should be used two or three times per day to remove deposit.

Safety valves should be made to blow slightly by lifting them every day at least, and gauge-cocks should be tested frequently every day, and especially first thing in the morning.

Low-water alarms should give warning when the depth of water over the crowns of the furnaces is not less than $4\frac{1}{2}$ inches, and $5\frac{1}{2}$ would be better, and it is advisable to test them occasionally by lowering the water to the blow-off level. Dinner-hour is convenient for this, as the boiler may be filled up, and steam got up again before starting time.

It is specially important that all steam-pipes, feed, and steam connections, and blow-out pipes should not be bound in brickwork or so arranged as not to admit of free movement and expansion, as fractures from pipes being bound fast frequently occur, often disastrously to the attendants. The following figures represent the mode of setting the Lancashire boiler, so as to facilitate cleaning and inspection. The dimensions of flues here given should not, if possible, be made less.

Fig. 93 is a cross-section of the boiler and flues, and Fig. 94 a sectional elevation of the back end of the boiler, the section passing clear of the end plate, as shown in Fig. 95, which is a longitudinal section of boiler and seating; Fig. 96 shows the plan of the brickwork. Figs. 97, 98, and 99 show various blocks for covering flues, &c. At Fig. 100 is given a section of the seating of the single-

fired, or Cornish boiler, and details are given of the fire-clay cover and seating blocks to a larger scale in isometrical perspective. Fig. 101 shows a general arrangement,

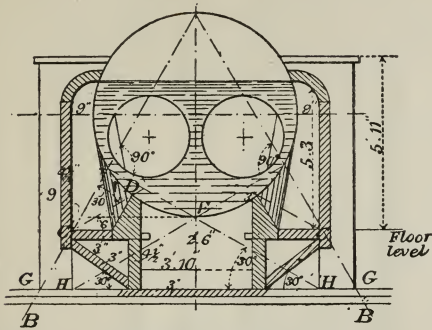


Fig. 93. Cross-section of boiler and seating.

in plan, of boilers, economizer, &c., for a mill of 70,000 or 80,000 spindles.

The method of setting out the flues of both the double

Section in C.D

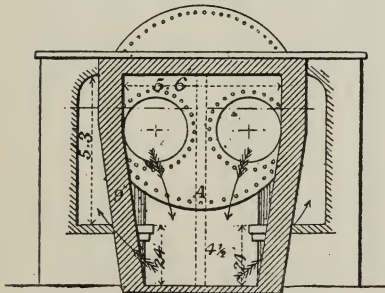
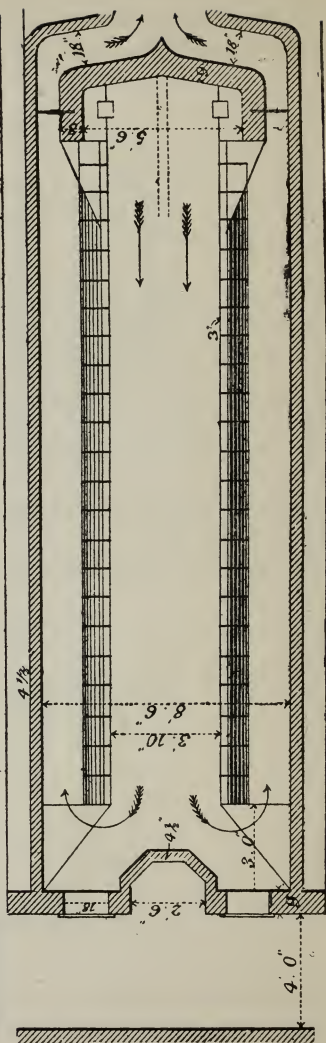
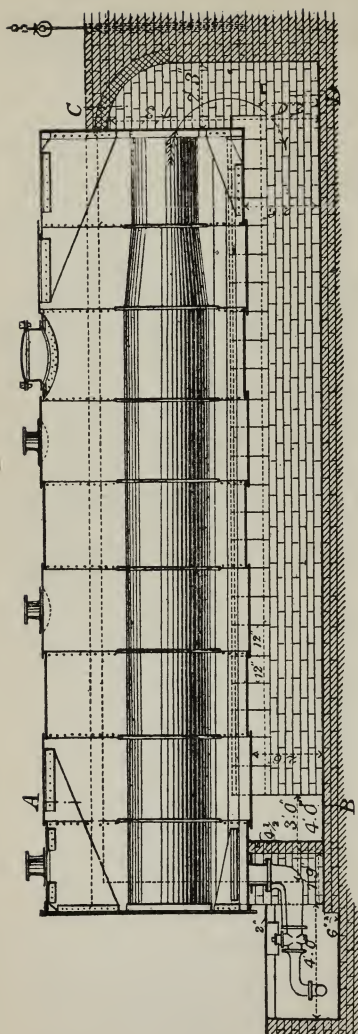


Fig. 94. Back sectional elevation.

and single flue boilers by the agency of a simple 30 and 60 deg. set square is too plain to require explanation.

Steam engines.—In regard to the question of steam



Figs. 95 and 96. Horizontal section and plan of seating.

engines, it may be said that fashion largely prevails in this matter. At one time nothing would do but beam-engines, now horizontal engines are almost universally employed.

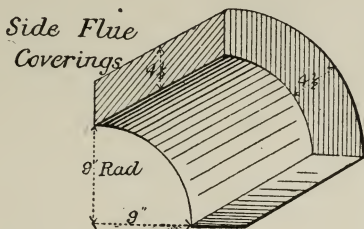


Fig. 97.

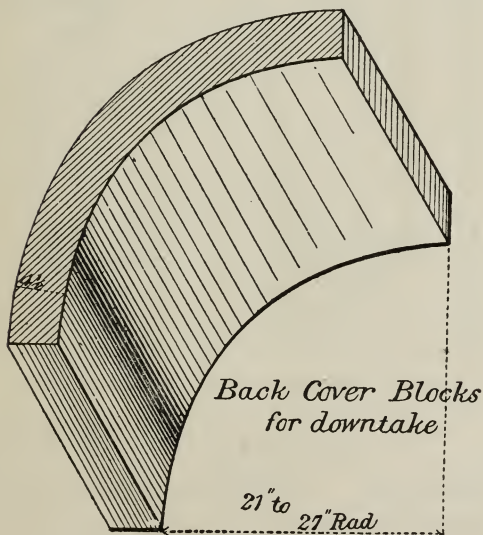


Fig. 98.

In the experience of the writer, taking into consideration large numbers of engines, the balance of economy in fuel consumption is on the side of the "McNaughted," or

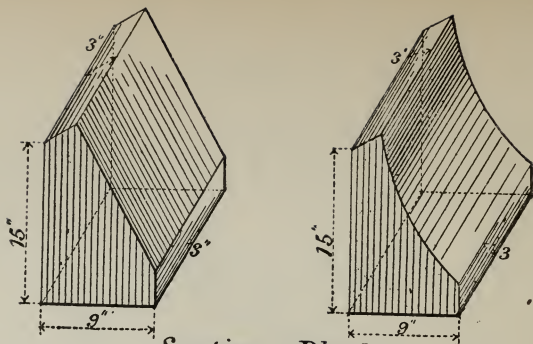


Fig. 99.

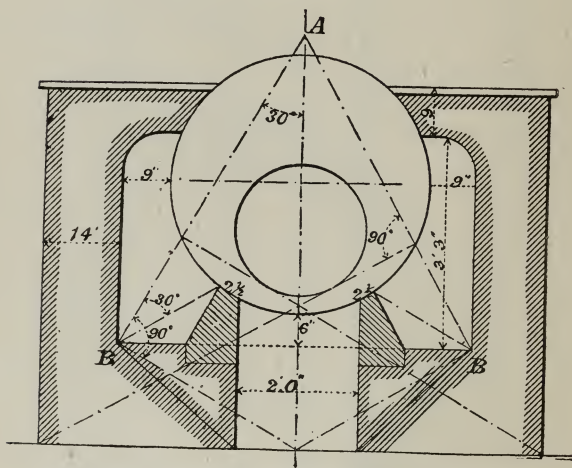


Fig. 100. Section of Cornish boiler and seating.

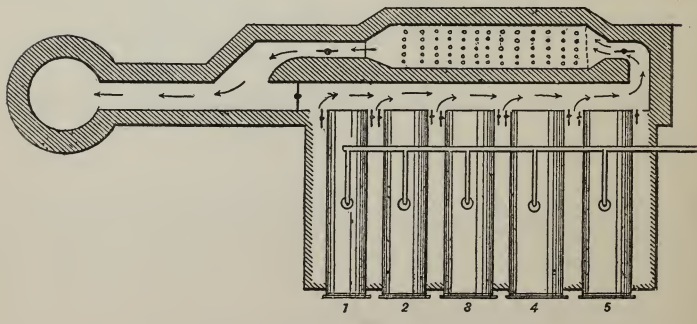


Fig. 101. Plan of boilers and economizer.

compound beam-engine, with the exception of compound horizontal engines, with at least the small cylinder properly steam-jacketed; and it is reasonable to suppose that the most economical engine would be the compound beam, with a satisfactory jacketing, and it should be more generally known that to jacket efficiently, steam of a higher pressure than that used in the engine must of necessity be employed; and, further, the working steam itself ought to be superheated to a moderate extent.

Cylinders must of necessity work more freely when vertical than when horizontal, and there is no reason why a properly constructed beam-engine should be either more expensive to construct, or more liable to break down than an horizontal engine; nor is there any reason why equally high piston speeds should not be attained, though it is clear that cast iron should not be employed in many situations that have hitherto been filled by it.

A good deal of misapprehension exists in regard to the engine question, and the writer does not expect to influence the fashion in the matter, but gives simply the result of a long series of observations.

Economizers.—The fuel economizer, to absorb much of the heat of the products of combustion between the boiler and chimney, is almost universal. An economizer of the standard or Green type consists of a series of vertical pipes 9 feet long and $3\frac{3}{4}$ inches internal diameter, arranged in rows to the number of 6, 8, or 10 pipes per row, and these individual rows of pipes are placed side by side to any required number, as many as 320 pipes existing in some sets, a convenient number of pipes being from sixty-four to ninety-six per boiler.

The temperature of the gases entering the economizer is commonly found between the limits 700° F. and 450°, being usually about 600°. In passing through the apparatus the gases impart heat to the feed-water in the pipes, and pass away to the chimney, reduced from 100° to 250° in temperature, commonly falling to about 400°.

The averages of a large number of tests gives an inlet temperature of 555° , an outlet temperature of 377° , equal to a fall of 178° ; but this average includes many cases of insufficiency of pipes. The rise of temperature of the water passing through the pipes at the same time averaged 106° , the greatest noted temperature being 285° , a rise of 187° from feed-water supplied at 98° .

In modern mills the economizer is usually placed at the back end of the boiler-house, transversely to the boilers. The main flue, which receives the ends of the boiler side flues, running between the back ends of the boilers and the economizer, and suitable provision being made to connect the main flue direct to the chimney, cutting the economizer out of the circuit for purposes of repair or cleaning. Economizers require cleaning and inspecting equally with boilers, and should not be neglected.

For a chimney draught, an economical temperature for the smoke is about 300° , and this may in time be generally obtained by a more rational arrangement of economizer than that generally made, which, though very good in practical use, is not a scientifically-arranged apparatus, and by many engineers is considered open to improvement.

Oil consumption.—In regard to the consumption of oil by engines, it has been found that one pint of oil will suffice for each indicated horse-power as many as 5,000 hours in favourable cases, the best results being obtained from beam-engines; 2,000 to 3,000 hours being a fair average duration of a pint per horse-power, the expenditure of tallow per horse-power at the same time being at the rate of a pound in about a third to a fifth of the same time.

Driving.—The method of driving by ropes appears to be likely to prove permanent, at least for some time. The capacity of a rope to drive is directly dependent upon its velocity: at 4,000 feet per minute, a two-inch cotton rope is considered equal to fifty horse-power.

Mechanical stokers.—The question of stoking by machinery is an open one. The writer knows of many successful stokers, and also of many the very reverse, and would not like to express any general opinion on the matter. So much depends on environment in this matter that nothing but an inspection of the whole surroundings of a boiler to which it is proposed to apply stokers will suffice to arrive at a proper conclusion.





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